LAKE ONTARIO FISHERIES UNIT

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CORRECTIONS TO 1990 ANNUAL REPORT

CHAPTER 5-4. TABLE 3 Caption 1st line - Delete "*attached*"

CHAPTER 20-1. Authors should read - T. J. Stewart and D. G. "*Robertson*"

CHAPTER 24-5. TABLE 3, Total, Column "$\bar{x}$", Numbers should read:
"*43.3, 47.5, 41.9, 40.3, 51.1, 35.9, 41.8*"

CHAPTER 24-5. Text, right column, 2nd paragraph, 10th line should read - *(mean = 41.8%)*

1990 ANNUAL REPORT
LAKE ONTARIO FISHERIES UNIT

Prepared for the
Lake Ontario Committee Meeting
Great Lakes Fishery Commission
Buffalo, New York
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Lake Ontario Fisheries Unit
Ontario Ministry of Natural Resources
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1990 ANNUAL REPORT
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TABLE OF CONTENTS

Lake Ontario Fisheries Unit Program Summary . . . . . 1 - 1

Outboard Trawling in Eastern Lake Ontario and the Bay of Quinte, 1990 . . . . . 2 - 1

Smelt Abundance and Growth in Western Lake Ontario . . . . . 3 - 1

Stocking Assessment of Brown Trout, Rainbow Trout, and Coho Salmon in the Boat Fishery of Western Lake Ontario . . . . . 4 - 1

OMNR's Zebra Mussel Monitoring Program on Lake Ontario, 1990 . . . . . 5 - 1

Detection of Zebra Mussel Veligers in Plankton Samples Using Sugar Solution . . . . . 6 - 1

Gillnet Survey in the Western Basin of Lake Ontario . . . . . 7 - 1

Estimates of the Total Angling Harvest in the Canadian Waters of Lake Ontario in 1989 . . . . . 8 - 1

Alewife and Smelt Catches in Midwater Trawls During the 1990 Survey of Lake Ontario . . . . . 9 - 1

Status of Lake Whitefish Populations in Eastern Lake Ontario . . . . . 10 - 1

Preliminary Report on the Salmonid Fishery in Western Lake Ontario . . . . . 11 - 1

Trends in Nutrient and Biological Variables in the Off-Shore: A Preliminary Report of the Lake Ontario Biomonitoring Program . . . . . 12 - 1

Bay of Quinte Angling Surveys, 1990 . . . . . 13 - 1

Lake Whitefish Spawning Shoal Observations at Four Bay of Quinte and Eastern Lake Ontario Sites . . . . . 14 - 1

Lake Ontario Hydroacoustic Survey for Alewife and Smelt . . . . . 15 - 1

Surveillance Report for Lake Trout Rehabilitation in Lake Ontario, 1990 . . . . . 16 - 1

Lake Ontario Stocking and Marking Program for 1990 . . . . . 17 - 1

Status of Selected Fish Populations in Eastern Lake Ontario . . . . . 18 - 1

Walleye Population in Eastern Lake Ontario and the Bay of Quinte, 1990 . . . . . 19 - 1

Lake Ontario Temperature Studies . . . . . 20 - 1

Research Project: Fish Community Dynamics of the Outlet Basin of Lake Ontario . . . . . 21 - 1

Research Project: Fish Community Studies of the Bay of Quinte . . . . . 22 - 1

Research Project: Sampling Variability of the Fish Community of the Outlet Basin of Lake Ontario . . . . . 23 - 1

Research Project: Lake Trout Rehabilitation Studies . . . . . 24 - 1

Lake Ontario Fisheries Unit
1990 Program Summary

T. J. Stewart and J. M. Casselman

Ontario Ministry of Natural Resources
Lake Ontario Fisheries Unit
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Introduction

Since 1984, Lake Ontario Fisheries Unit (LOFU) staff have prepared an annual report summarizing work undertaken during the previous fiscal year (12 month period between April 1 and March 31). The annual report is intended to keep scientists and managers who work on Lake Ontario informed of LOFU activities, and to promote cooperation and interaction among these groups. Chapters in the annual report are written to highlight information of interest to Lake Ontario fisheries managers; they are not intended to be substitutes for refereed, journal publications. Some projects do not produce immediate results, and some tasks do not warrant reports. The purpose of this introduction is to tie up any loose ends by summarizing tasks and information not presented elsewhere. This includes:

1. A summary of Assessment and Research programs, project leaders, and other ongoing activities;
2. A summary of research papers published by LOFU staff during 1990;
3. A list of LOFU staff; and
4. A report on commercial fishery landings in eastern Lake Ontario.

Summary of Assessment Activities During 1990/91

Six programs involving 21 projects were conducted during 1990/91. A list of project names and associated project leaders is included in Appendix 1. A variety of special projects were also undertaken during 1990. The following summarizes all programs and special projects and, where applicable, indicates source chapters in the 1990 annual report.

Fish Community Indexing

The highest priority for LOFU Assessment is to develop and maintain indices of fish population abundance to detect long-term fish community changes. In 1990, there were six community indexing projects. The outboard trawling program (Chapter 2), designed to index the abundance of small fish in the Bay of Quinte and nearshore habitats of eastern Lake Ontario, was continued in 1990. Smelt bottom trawling, in the western basin of Lake Ontario (Chapter 3), was again completed successfully in cooperation with the U.S. Fish and Wildlife Service (USFWS), and provides our only long-term index of smelt abundance in western Lake Ontario. In cooperation with the New York Department of Environmental Conservation (NYDEC), we were successful in making the first lakewide estimates of smelt and alewife abundance using midwater beam trawls (Chapter 9). We learned much from this program, and are continuing to improve and develop a broader, and more accurate, means of indexing pelagic fish communities. Hydroacoustics show promise in this regard and the pilot project initiated in 1990, demonstrated the value of this technology (Chapter 15). Our ability to design and interpret lakewide surveys will benefit from studies of fish habitat; to date concentrating on describing regional differences in thermal habitat structure (Chapter 20). Index gillnetting in eastern Lake Ontario was continued in 1990 and was used to update the status of numerous fish species (Chapter 10, 14, and 19). A pilot study using bottom gillnets in western Lake Ontario, and a review of similar historical research bottom gillnet series, concluded that this gear was not appropriate for providing a long-term community index in western Lake Ontario (Chapter 7).

Lake Trout Rehabilitation

Lake trout assessment continues to be guided by the "Joint Plan For the Rehabilitation of Lake Trout in Lake Ontario". An updated version of the plan, prepared by OMNR, NYDEC and the USFWS, will be released in 1991. These agencies participate in a cooperative yearly sampling program, collecting data on abundance, survival, and population structure of lake trout and determining lamprey impacts (Chapter 16).

Lake trout sport harvests were monitored during western and central basin creel surveys (Chapter 11). The "Peter Rock" shoal, near Port Hope, Ontario, was surveyed by divers to determine the extent of potential lake trout habitat. The results of the survey indicate, small, widely dispersed areas of potential spawning rubble, and further work on this shoal was abandoned.

During April and May of 1990, fry traps were placed at Yorkshire Bar and Stoney Island in an attempt to catch lake trout fry emerging from these shoals. The work was a cooperative venture involving staff from OMNR, NYDEC and Cornell University. Numerous fry were captured at Stoney Island and one fry was captured at Yorkshire Bar (Chapter 16). Observations of spawning lake trout and egg density surveys of Yorkshire Bar, conducted by the Research group (Chapter 24), have determined more specific areas of egg deposition. Based on this information, we expect fry trapping on Yorkshire Bar to be more successful in 1991.

A study to determine the feasibility of using radio biotelemetry to locate lake trout spawning shoals was completed by Lotek Engineering Ltd., Aurora, Ontario, in cooperation with LOFU and the Kawartha Lakes Fisheries Assessment Unit. The results were very positive, and led to plans for a pilot study in 1991.

Salmonid Assessment

Fish stocking statistics for 1990 were compiled and reported (Chapter 17). A large portion of the salmonid fishery in Lake Ontario, primarily lakeshore and stream fisheries, remains unsurveyed, hampering our ability to fully assess the salmonid stocking program. However, using partial surveys, stocking rates, relative sizes of migratory fish runs, trends in fishing effort, and antecdotal information, an estimate of total angling harvest for Canadian waters was derived. These estimates should be valuable in a planning context (Chapter 8). Further analysis of all available information on the returns of Ontario stocked brown trout, rainbow trout, and coho salmon, was synthesized and management recommendations provided (Chapter 4). The salmonid angling surveys were continued in 1990 (Chapter 11), as were coho, chinook, and rainbow trout spawning migration monitoring programs (not reported). Scale samples collected during these surveys will be used to develop techniques to distinguish between fish of native and hatchery origin, as was done previously for rainbow trout (see Research summary below).

Lake Whitefish Assessment

The status of lake whitefish populations in eastern Lake Ontario was updated using information from a variety of projects (Chapter 10). Work on discriminating Lake Ontario and Bay of Quinte whitefish stocks, based on characteristics of calcified structures, continued in 1990 (see Research summary below), and will enhance our ability to manage whitefish stocks. In response to anticipated zebra mussel colonization, several lake whitefish spawning shoals were surveyed in the Bay of Quinte and Lake Ontario. Zebra mussel were not detected (Chapter 14).

Walleye Assessment

Trends in walleye abundance in eastern Lake Ontario index gillnets were examined (Chapter 18), and angling statistics for the Bay of Quinte were summarized (Chapter 13). Information from these sources, commercial fish statistics, and the 1989 Bay of Quinte mark-recapture project, were synthesized into one report updating the status of walleye (Chapter 19). The synthesis report also simulated future walleye populations in the Bay of Quinte, using an age-structured model, and explored the consequences of changes in the angler "bag limit" and commercial fishery quotas.

Zebra Mussel Monitoring

Sightings of zebra mussel in Lake Ontario became more frequent through the summer of 1990. In response to the invasion, LOFU initiated a monitoring program (Chapter 5) which, in conjunction with similar studies by NYDEC and the USFWS, will document the extent of the invasion lakewide. Monitoring of this organism is new to Ontario investigators, and will require development of innovative approaches. One such innovation, which facilitates efficient detection of zebra mussel in plankton samples, was developed at LOFU (Chapter 6). Past development and support for established fish

community monitoring programs, as reported throughout this annual report, will provide a sound basis for understanding and dealing with resource management problems resulting from the zebra mussel invasion. Much work is still required to address information gaps; the 1990 survey of lake whitefish spawning shoals, and associated recommendations for follow-up work are good examples (Chapter 14).

Special Studies

A variety of special studies were initiated in 1990. Increased stocking of salmonids has raised concerns about placing excessive demands on the existing forage base. In response, LOFU participated in multi-agency workshops, led by Dr. M. Jones (OMNR), Dr. J. Koonce (Case Western Reserve University, Cleveland, Ohio) and Mr. G. Christie (Great Lakes Fishery Commission), that resulted in the the development of a predator prey model which simulates alewife and salmonine population dynamics. This model has proven valuable in exploring management options in the face of a recurrence of an alewife population collapse. The model also identified the need for better estimates of standing stock and age-structure of salmonine populations, and was the incentive for a special project to analyze a time-series of salmonine sport fish harvest. Reporting of these results await incorporation of American harvest data.

A draft of the Lake Ontario management plan was completed in 1990 and is currently under review. The first estimates of total angling harvest for the Canadian waters of Lake Ontario were completed under the auspices of the plan (Chapter 8).

Unique to the 1990 LOFU annual report is the inclusion of a report of the Lake Ontario bio-monitoring program conducted by the Department of Fisheries and Oceans (DFO), and Environment Canada, Inland Waters Directorate (Chapter 12). Our intent was to make current information on water chemistry and the "lower" trophic levels of Lake Ontario readily available to fisheries managers. Similarly, with the cooperation of the National Water Research Institute of Environment Canada, we were able to gain access to archived digitized Lake Ontario temperature profiles for the period 1960 to 1990, and are using these data to improve the design and interpretation of lakewide fish sampling programs (Chapter 20). We see these projects as a small step towards both, communicating and emphasizing the need for such programs from a fisheries management context, and to encourage development of more lakewide integrated and cooperative studies.

Other Work Involving LOFU Staff

Periodically, the results from the above studies are published in scientific journals. A list of recent publications of both Research and Assessment staff is presented in Appendix 2.

Ted Schaner and Tom Stewart were both actively involved in two of the Provincial Lake Trout Synthesis working groups. Reports from both working groups are now available (for complete references see Appendix 2). One report examines lake trout sampling issues and standards, while the other examines the harvest potential and dynamics of lake trout populations in Ontario lakes.

On occasion, LOFU staff are called upon to serve on committees or conduct work outside our normal programs such as fish stocking, and collection of fish for contaminant analysis. A summary of these tasks is presented in Appendix 3. A list of all staff at LOFU during 1991 is presented in Appendix 4.

Commercial Fishing Landings in Napanee District

Commercial landing statistics are included in this report for reference. During the 1990 calendar year, commercial fishermen reported harvesting a total of 1,163,472 pounds (round weight) of fish with a landed value of $907,408.80. A more detailed summary is provided in Appendix 5.

Summary of Research Activities During 1990/91

Four major research projects were conducted during 1990/91 and are included in some detail in separate chapters in this annual report. These involve: (1) fish community studies of the Outlet Basin of Lake Ontario (Chapter 21), (2) fish community studies of the Bay of Quinte (Chapter 22), (3) sampling variability studies (Chapter 23), and (4) studies of the factors affecting lake trout rehabilitation (Chapter 24). Other research projects are being conducted and are at various stages of completion. However, these will not be reported in detail here. Several of them involve age-growth research. Some projects were not funded in 1990/91 and await either time or special funds before they can be continued. The status of these projects and a general review of ongoing research activities during 1990/91 that will not be reported elsewhere follow.

Mr. Jack Christie retired officially in June 1990 after a long and distinguished career in Fisheries Research with the Ontario Department of Lakes and Forests and the Ontario Ministry of Natural Resources. Much of his work involved Lake Ontario and its fish communities. We wish Jack many years of happy, healthy, and productive retirement. From his home at Glenora, Jack is pursuing his interest in fisheries by working on economic development and sustainable fisheries, and he continues to help organize and maintain a sustainable fisheries network and uses his many years of experience to consult on aquatic ecosystems.

Dr. Peter Sly, who works for the Department of Fisheries and Oceans Canada in Burlington, and with the Rawson Academy in Ottawa, continues to maintain his office at Glenora and assists in consultation with OMNR and the Great Lakes Fishery Commission on specific habitat concerns involving natural reproduction and rehabilitation of lake trout stocks.

Plans are being discussed for Dr. Mike Jones and the Great Lakes Salmonid Research Unit, currently located at Maple, to transfer to the Glenora Fisheries Station. Mike is currently working on several important research problems associated with Lake Ontario. These involve modeling predator-prey interaction and specifically concern overstocking of hatchery predators in Lake Ontario. He researches the Atlantic salmon re-introduction in Lake Ontario and is studying salmonid ecology and production in the tributary streams along the north shore of the lake.

Dr. Donal Hurley, Research Scientist in the Research Unit, participates actively with the Project Quinte group, which is currently considering preparation of a set of publications that would review and update the ecosystem changes that have gone on in the Bay of Quinte since 1982 and were published in 1986 in the Canadian Special Publication of the Fisheries and Aquatic Sciences, (No. 86).

Dr. John Casselman, Senior Scientist in the Research Unit, continues as a Conjunct Professor at Trent University and is involved in the graduate student program and assists the School of Graduate Studies by reviewing M.S. theses and participating on graduate student committees and as a member of examining committees for postgraduate oral defences. He continues as an advisor to the CIDA limnology project that jointly involves the University of Waterloo and Addis Ababa University in Ethiopia. He has assisted Dr. Bill Taylor, of the Biology Department, in preparing a proposal to CIDA to fund another similar joint project that will train three Ethiopian fisheries biologists at the Ph.D. level. At present, only three Ethiopian Ph.D.'s have any specific fisheries training, and their fields of research are very specialized. John Casselman continues as a Research Associate at the Royal Ontario Museum. He continues his long-standing association with Dr. Ed Crossman and their joint involvement with muskellunge and northern pike research and the Cleithrum Project.

From time-to-time, universities and researchers confer with Research staff, work on joint projects, and obtain data and occasionally fish samples. A few who have been very recently involved are Dr. Allen Weatherley, Scarborough Campus, University of Toronto, who is studying electronic detection of activity patterns of walleye; Dr. Richard Jarvis, State University of New York, who is studying stock recognition in whitefish populations by means of shape analysis of calcified structures; Dr. Neil Loneragans, CSIRO Marine Laboratory, Queensland, Australia, who will be conducting multivariant analysis to examine species interaction in the fish community of the outlet basin of Lake Ontario; Dr. Bruce Tufts, Biology Department, Queen's University, who plans studies involving stress associated with catch and release of angled fish; Dr. Milton Suboski, who studies fish behaviour with special reference to life-skills training for hatchery fish; Dr. Eric Taylor, Department of Biology, Dalhousie University, who is studying the geographic variations in mitochondrial DNA among populations of rainbow smelt; and Dr. Steve Campana, Department of Fisheries and Oceans Canada, Dartmouth, who is using shape-analysis software developed for a microcomputer, which can be used to analyze stock differences to separate cod stocks of the western North Atlantic.

In 1990/91, Dr. John Casselman and Dr. Donal Hurley reviewed and refereed ten manuscripts submitted by editors of primary journals. Seven of these manuscripts pertained to age and growth research. Five research proposals were reviewed for major granting agencies; one, for example, came from the National Science Foundation in the United States and dealt with age and growth studies of Arctic fishes. They also gave several invited talks, including three to organized fishermen's clubs associated with Lake Ontario. John Casselman and Dr. Tad Penczak submitted the manuscript on evaluating fish sampling methodologies for large river systems to Polish Archives of Hydrobiology. The manuscript, which includes an extensive survey of riverine fish-sampling techniques, was prepared as a result of the deliberations of a working group convened at the Large River Symposium held in 1986. It was submitted to Pol. Arch. Hydrobiol. because it is a leading international publisher of scientific papers on riverine fish and fisheries. The paper has been accepted for publication and will appear in 1990, Vol. 37, No. 4.

The Age, Growth, and Environmental Studies (AGES) research program conducted by John Casselman, which has a provincial mandate and scope, is now conducted under the auspices of the Research component of the Lake Ontario Fisheries Unit and its facilities at Glenora. In 1990, Joe Dibbits continued on his long-term B-salary contract, assisting with the technical aspects of this research program. However, this important support had to be terminated in June, when B-salary funds dedicated to Age-Growth Research ran out.

Research conducted by the AGES Unit is aimed at refining, improving, and testing the validity of methods of age interpretation and growth estimation of fish from their calcified structures. Research is being conducted to develop new labelling procedures that can be used to validate age interpretation more easily. In conjunction with these studies, the program conducts research into the effects of environmental factors on growth and production of the fish, especially those affected by stress. Studies conducted in the natural environment provide fish and calcified tissues that are marked and labelled and are of known age and partly known age.

Until recently, the field program that provided this material and the focus of research studies of this research program was in lake trout lakes in the Haliburton Highlands of Ontario. The field-collection phase of the Haliburton study is essentially complete, although some sampling of marked fish is conducted from time-to-time. Analyses of the data and samples are underway but progressed slowly because the amount of technical support dedicated to this program has been restricted in 1990. Large numbers of fish were labelled with tetracycline in this study to provide a method for validating age determination and growth estimation. Tetracycline-labelled calcified tissue still needs to be removed from frozen fish carcasses. It is imperative that this be done soon so the study can be completed, because it is no longer possible to use this marking method in the natural environment since the administering of chemicals to wild fish, has been greatly curtailed and, in this case, tetracycline, prohibited.

Some aspects of age-growth research are now being directed specifically at problems associated with Lake Ontario fishes. Software has been developed that uses Fourier series analysis to identify and distinguish among stocks, based on scale and otolith shape. Shape analysis is being conducted with a digitizing tablet and a microcomputer. Application of the technique is being used to examine stock discreteness for "bay" and "lake" stocks of lake whitefish in the Eastern Basin of Lake Ontario. Samples were collected on the spawning grounds of these two stocks in the fall of 1988 and again in 1990. Shape and age data have been collected on the scales and otoliths of the 1988 samples. However, the 1990 samples have not yet been processed. When this is complete, samples collected during the summer in the eastern basin will determine the degree of summer mixing. Scale age interpretations for the 1988 samples of lake whitefish have been examined. Results indicate disturbing inconsistencies, so otoliths and the acetate replication technique are being used to systematically review precision and accuracy of the age determination of this species.

One of the major initiatives of this age-growth research for Lake Ontario species will be directed towards providing validated year-class strength determinations for current and historic fish-community dynamics studies of the outlet basin and the Bay of Quinte. Only after this has been done will it be possible for the effects of environmental factors and species interaction to be precisely quantified and predicted.

Development of the Calcified Structure Age and Growth data Extraction System (CSAGES) by John Casselman and Ken Scott is progressing well. The software and a supporting technical manual are being prepared and will be available for distribution in 1991. This system interfaces a computer and a digitizer and permits the interpretation of checks and zones in the calcified tissue of fish to be fully recorded and quantified so that age and growth determination problems can be easily and systematically recognized and solved. The software system was specially developed to facilitate growth studies of calcified tissue and to remove the mystery associated with "reading" age from fish calcified structures. This mechanized interpretation system is currently being tested in several research applications and is being used in three contracts that have been privatized with COA funds to examine a subsample of scales from three species--white perch, walleye, and lake whitefish--taken over the past 30 years from the index sampling conducted by Research in the Bay of Quinte and eastern Lake Ontario.

In June, John Casselman was invited by Northwestern Region, OMNR, to their Regional Fish and Wildlife annual meeting to present this new age and growth interpretation methodology and software. During the trip to the meeting, which was held at a remote fly-in camp near Sioux Lookout, the District arranged gill-net sampling of two remote fly-in lakes. This was done in order to obtain fish from walleye and lake trout populations that are considered to be unexploited. Calcified structures have been removed from these fish and will be used to determine the mortality rate of unexploited populations of these species. In both cases, the fish were not extremely large, but the largest individuals showed considerable emaciation and little or no visceral fat, with some females showing atrophy of the eggs. Other individuals appeared sterile.

A major study of the relative growth of the calcified structures of fish was completed and published in the July 1990 issue of Transactions of the American Fisheries Society. For a complete reference, see Appendix 2. This work explains why otoliths in slow-growing or older fish continue to record cyclic seasonal growth and provide an accurate interpretation of age, whereas structures such as scales may fail to grow in a regular fashion in these fish and may not provide an accurate interpretation of age.

Techniques are being developed to use calcified tissue to recognize the origin of young fish, especially to determine whether they are from a hatchery. Studies also involve chemical marking of calcified tissue so that it provides direct evidence as to origin. This permits a definitive method of assessing the success of stocking techniques. For the past several years, techniques involving scales, otoliths, and chemical marking have been conducted on young walleye as part of the walleye-stocking assessment program of Eastern Region, OMNR. Two agencies outside the Province of Ontario and a number of OMNR districts and regions are currently using these techniques. North Bay District has provided B-salary funds that are being used under the auspices of the Age-Growth research program to process a large number of walleye otoliths that have been collected to assess hatchery origin and evaluate the contribution of walleye culture programs in North Bay District. Final manuscripts associated with this work are being prepared. They involve: (1) a study of the use of scale characteristics; (2) an examination of otolith microzonation, which has been shown to provide valid age in days for at least the first 4 months of life; and (3) marking the otoliths by immersing the fish in a dilute solution of stable strontium chloride. Strontium has been shown to change not only the chemical composition but also the optical appearance of the otolith. Field trials that have examined the practical applications of these marking methods have recently been completed.

The manuscript on distinguishing between indigenous and hatchery lake trout by means of otolith and scale characteristics has been submitted for publication, reviewed, is being revised, and will shortly be resubmitted for publication.

The preliminary study that was funded by Assessment and was conducted and reported in 1989, which indicated that scale and otolith characteristics could be used to distinguish between rainbow trout of native and hatchery origin, was not funded in 1990. However, some calcified-structure samples were collected from indigenous rainbow trout in Lake Huron and can be used to refine and improve the study when funds are available to continue and complete this research.

John Casselman has been asked to be a member of a steering committee, with representation from six countries, for an international otolith symposium that will be convened in 1993 to review fish-otolith research and applications. He has also been invited to submit a manuscript to a special issue of the Australian Journal of Marine and Freshwater Research that will be published in book form and will be devoted to papers on the age and growth of fish and other aquatic organisms.

Research Involvement With College and University Students and Graduate Programs

Yosef Tekla-Giorgis, a CIDA-sponsored graduate student enrolled in an M.Sc. program at the University of Waterloo and supervised by John Casselman, completed his research at the Glenora Fisheries Station, where he used the facilities to interpret and analyze age and growth of *Tilapia* from Lake Awassa, a Rift Valley lake of Ethiopia. He submitted his thesis and successfully defended it and was granted his degree by the University of Waterloo. The thesis was nominated by the biology department for the award of Master of Science thesis of the year at the University of Waterloo. He developed a system using otoliths, which can be used to accurately assign not only age and year- class but also specific biannual recruitment cohort in a population of tropical fish that spawn throughout the year but have two major peaks of spawning activity with two corresponding recruitment cohorts. From his research he was able to determine the age in days of fish that were several years old.

Kevin Reid, a graduate student of Dr. Whillans at Trent University, who studied pike spawning and nursery requirements in Wilcox Lake, Ontario, and conducted analyses in the Age-Growth laboratory at the station under the supervision of John Casselman, completed his thesis and successfully defended it at Trent University. John Casselman was a member of both the graduate student and oral examination committees.

Cheryl Podemski, working with Dr. Roger Green in the Department of Biology, University of Western Ontario, completed her field collections for her M.Sc. thesis, which involved studying production and biomass at various locations along the trophic gradient that exists down the Bay of Quinte. This study is very important and timely since it precedes the impending invasion of zebra mussel in the Bay of Quinte. Dr. Robert Bailey, professor in the same department, is conducting a study that involves describing potential zebra mussel habitat and will test a model that predicts the invasion of zebra mussel in the Bay of Quinte. He is conducting this research through a graduate student program.

Bruce Rich, of the University of Utah, is working on a Master's thesis involving pike populations in lakes in Utah. He has been consulting with John Casselman, who is advising on his thesis. A review of the age-growth data of pike from

these lakes indicates that they are among the fastest growing populations ever documented. In four years, the pike reach 100 cm in length.

Andrea Brown, of the University of Toronto, is completing an undergraduate thesis for course credit that involves the study of the age, growth, and production of lake trout in an exploited Alaskan lake. She is consulting John Casselman, and he is advising on this program, which is co-supervised by Dr. Ed Crossman of the Royal Ontario Museum and Dr. Harold Harvey of the Department of Zoology, University of Toronto. Andrea is using the Age-Growth Research facilities at Glenora to study calcified structures that she has collected and is using the CSAGES software system to perform the interpretation and analysis.

The third-year fisheries course of Sir Sandford Fleming College attended the station and were given a one-day seminar by Assessment and Research; included was a presentation on the science and technology of age and growth determination of fish. John Casselman gave the Age-Growth section, with lecture and laboratory components, to the fourth-year and graduate student Ichthyology course at the University of Toronto.

Provincial Lake Trout and Walleye Data Synthesis

John Casselman was actively involved in two reports that were prepared for lake trout synthesis. Both reports are now complete. One report involves anthropogenic stressors and diagnoses of their effects on lake trout populations in Ontario lakes. This study was multi-authored. The specific reference for this report is provided in Appendix 2.

For the other study, which involved analysis of data from 9% of Ontario lake trout lakes, habitat and environmental conditions that affect lake trout recruitment were quantified and analyzed. The specific part of the study that he dealt with considers the effects of the loss of deep-water nursery habitat and adult suppression of the productivity of native lake trout stocks. This research provided direct evidence that there must be adequate quantities of well-oxygenated deep-water nursery habitat for juvenile lake trout if there is to be significant natural recruitment. The specific reference for this report is also provided in Appendix 2.

Although the provincial walleye synthesis exercise is still only in the planning phase, Don Hurley and John Casselman have begun a study on a subset of walleye data that have been collected in the past 30 years from the Bay of Quinte. The study, which will contributed to the synthesis exercise, involves a detailed analysis of the scales using the CSAGES software system. Validation of age and growth estimation will be performed, and the data will be used to construct age-length keys for each annual sample. These will be used to estimate age distribution, year-class strength, mortality rate, growth, and production for the Bay of Quinte walleye population for the past three decades. Scale interpretations are underway, using a private contract and COA funds. This work is being performed by Joe Dibbits.

A Review of Research Needs for Lake Ontario for the 1990s and Immediate Future Research PLans

The OMNR review of research needs for Lake Ontario for the 1990s, which was completed in 1989, was incorporated in an overall OMNR Great Lakes Research plan. This Great Lakes Plan was submitted to the Research Section Manager at Maple and received approval. The overall Great Lakes Research Plan integrates and reinforces the list of priorities prepared for Lake Ontario. The priorized list of research needs will be presented elsewhere. However, at this time, it is appropriate to underline the two most important research problems. They are to study and determine the factors that affect and limit the rehabilitation of lake trout stocks of Lake Ontario and to determine and quantify the factors that affect year-class strength of the most important sport and commercial species in the Bay of Quinte and the Eastern Basin of Lake Ontario. Species of special interest are walleye, white perch, and lake whitefish.

Traditionally, research was conducted around index sampling of the fish communities of the Bay of Quinte and the Outlet Basin of Lake Ontario. Future plans, which will include a transfer of this traditional role of community indexing to Assessment, will result in a redirection and focus by Research on more specific objectives. The 1991/92 field season will be the last year that Fisheries Research will maintain its community indexing role in the Bay of Quinte and Lake Ontario. During the past two seasons, sampling variability has been measured for the gear used and community sampled in these two 30-year sampling series. Some of the preliminary results of these studies are reported in Chapters 22 and 23 of this report. During the 1991 summer season, Research will continue to sample at the traditional stations (only three of the original six will be used in the outlet basin). But this will be done to compare catches in the new monofilament gill nets, which will become the Lake Ontario experimental gill-net standard, with those of the traditional multifilament nets. This will be done so that historic catches can be converted to those associated with the new standard gear. It is intended that this comparison will be completed during the 1991/92 field season. New specific research projects that will meet research needs for the 1990s are currently being designed. Although Research will continue to have an ongoing interest in and will continue to analyze the Research index series, the main thrust will be towards short-term studies that focus on specific problems or processes.

Early life history research, including larval fish studies, will be of primary importance, specifically in the case of lake trout, to understand what is limiting rehabilitation, and in the case of walleye and lake whitefish, to quantify the factors that effect strong year classes, which have in recent years been dominant factors in the dynamics of these fish populations.

Acknowledgments

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APPENDIX 1. Programs conducted by the Lake Ontario Fisheries Unit between April 1, 1990 and April 1, 1991.

Assessment Programs

Fish Community Indexing

Outboard trawling
Project Leader: Jim Hoyle

Alewife/smelt midwater beam trawl survey (OMNR/NYDEC)
Project Leader: Alastair Mathers/ Clif Schneider

Western basin smelt bottom trawling (FWS/OMNR)
Project Leader: Jim Bowlby

Hydroacoustics development
Project Leader: Ted Schaner

Lake Ontario habitat studies
Project Leader: Tom Stewart

Eastern Lake Ontario assessment index gillnetting
Project Leader: Tom Stewart

Western Lake Ontario assessment index gillnetting
Project Leader: Jim Bowlby

Lake Trout Rehabilitation

Map Peter Rock Shoal
Project Leader: Tom Stewart

Fish fry traps at Yorkshire
Project Leader: Tom Stewart

Cooperative lake trout gillnetting (NYDEC/OMNR/FWS)
Project Leader: Ted Schaner

Salmonid Assessment

Salmonid boat angler survey
Project Leader: Jim Bowlby

Central region shore angler survey
Project Leader: Paul Savoie

Charter boat survey
Project Leader: Jim Bowlby

Credit River coho/chinook monitoring
Project Leader: Jim Bowlby

Ganaraska river rainbow trout monitoring
Project Leader: Jim Bowlby

Salmonid diet analysis
Project Leader: Jim Bowlby

Lake Whitefish Assessment

Lake whitefish spawning shoal surveys
Project Leader: Jim Hoyle

Walleye Assessment

Age-structured walleye population model
Bay of Quinte creel surveys
Project Leader: Alastair Mathers

Zebra Mussel Monitoring

Zebra mussel invasion monitoring
Project Leader: Ted Schaner

Special Projects

Lake Ontario total angling harvest
Project Leader: Paul Savoie

Salmonid catch-at-age-analysis
Project Leader: Jim Bowlby

Lake Ontario management plan
Project Leader: Paul Savoie

Lake Ontario biomonitoring program (DFO/DOE)
Project Leader: Dr. O. E. Johannsson

Lake Ontario predator prey model (LOPPM)
Project Leader: Dr. M. Jones

Research Programs

Fish community dynamics of the outlet basin of Lake Ontario
Project Leader: Dr John Casselman

Fish community studies of the Bay of Quinte
Project leader: Dr. Don Hurley

Sampling variability of the fish community of the outlet basin
Project Leader: Dr. John Casselman

Lake trout rehabilitation studies
Project Leader: Dr. John Casselman

Diet studies of fish of the Bay of Quinte
Project Leader: Dr. Don Hurley

Lake whitefish stock discrimination studies
Project Leader: Dr. John Casselman

Discrimination between hatchery and native rainbow trout
Project Leader: Dr. John Casselman

Development of a calcified structure age and growth data extraction system (CSAGES)
Project Leader: Dr. John Casselman

APPENDIX 2. Research papers published by LOFU staff during 1990.

CASSELMAN, J. M. 1990. Growth and relative size of calcified structures of fish. Transactions of the American Fisheries Society 119: 673-688.

EVANS, D. O., J. BRISBANE, J. M. CASSELMAN, K. E. COLEMAN, C. A. LEWIS, P. G. SLY, D. L. WALES, AND C. C. WILLOX. 1990. Anthropogenic stressors and diagnosis of their effects on lake trout populations in Ontario lakes. Lake Trout Synthesis, Ontario Ministry of Natural Resources, Toronto. 110 p.

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PAYNE, N. R., R. M. KORVER, D. S. MACLENNAN, S. J. NEPSZY, B. J. SHUTER, T. J. STEWART, AND E. R. THOMAS. 1990. The harvest potential and dynamics of lake trout populations in Ontario. Lake Trout Synthesis, Ontario Ministry of Natural Resources, Toronto. 72 p.

APPENDIX 3. Other work involving LOFU staff.

Description	Staff
1. Rewrite of the lake trout rehabilitation plan.	Ted Schaner
2. Lake Trout Synthesis sampling methodology working group	Ted Schaner
3. Lake Trout Synthesis population dynamics working group	Tom Stewart
4. Lake synopsis review committee	Tom Stewart Jim Bowlby
5. Fish stocking	Chuck Wood
6. Collection of fish for contaminant analysis	Dawn Walsh Steve Lawrence

APPENDIX 4. LOFU staff in 1990.

LOFU Staff at Glenora

Dave Jeffrey, Operations Supervisor
Dr. John Casselman, Senior Research Scientist
Dr. Don Hurley, Research Scientist
W. Jack Christie, Great Lakes Research Coordinator
Dr. Peter Sly, Visiting Scientist (Rawson Academy)
Cheryl Lewis, Warmwater Fisheries Specialist

Tom Stewart, FAU Supervisor
Ted Schaner, FAU Biologist
Alastair Mathers, FAU Biologist
Jim Hoyle, FAU Biologist

Ken Scott, Computer Systems and Database Manager
Kelly Sarley, Data Entry

John Kinney, Administrative Clerk
Carol Ward, Secretary/Administrative Support/Library
Linda Balsillie, Secretary/Reception/Administrative Support
Linda Blake, Secretary/Administrative Support

Dawn Walsh, Senior Technician-Field Operations
Chuck Wood, Senior Technician-Marine Service
Wayne Miller, Senior Technician-Base Operations
Jeff Church, Age Determination Technician
Dale Dewey, Technician
Steve Lawrence, Technician
Joe Dibbits, Technician
Tim Shannon, Technician
Steve Welham, Technician
Terry Cronin, Technician
Randy Gurnsey, Technician
Alden Drost, Technician
Ambrose McCambridge, Technician
Tom Lawrence, Technician
Gord Giles, Boat Captain
Alan McIntosh, Boat Captain

LOFU Staff at Aurora

Jim Bowlby, FAU Biologist
Paul Savoie, Fisheries Management Planning
Celine Plante, Biologist

APPENDIX 5. Commercial Landings in Napanee District. Prepared by Dave Montgomery, Fisheries Management Officer, Napanee District.

Species	1990 Harvest (lbs)	Price per lb (dollars)	1990 Value (dollars)
Bowfin	1,550	0.18	271.00
Bullheads	220,195	0.42	90,824.23
Carp	88,188	0.27	23,888.10
Catfish	25,240	0.26	6,566.30
Crappies	16,388	1.55	25,337.75
Drum	10,745	0.35	3,757.62
Eels	192,067	1.17	224,728.76
Lake herring	5,345	0.41	2,182.35
Lake whitefish	276,169	0.84	231,333.40
Rock bass	14,445	0.24	3,458.05
Sunfish	37,218	0.37	13,878.67
Suckers	13,718	0.20	2,693.42
White bass	2,250	0.65	1,470.66
White perch	53,779	0.34	18,343.39
Walleye	25,461	0.89	22,580.49
Yellow perch	180,694	1.33	236,094.61
Total	1,163,452		$907,408.80

Outboard Trawling in Eastern Lake Ontario and the Bay of Quinte, 1990

J. A. Hoyle

Ontario Ministry of Natural Resources
Lake Ontario Fisheries Unit
R. R. # 4, Picton, Ontario K0K 2T0

Lake Ontario Fisheries Unit, 1990 Annual Report, LOA 91.1 (Chapter 2)

The Lake Ontario Fisheries Unit conducted an outboard trawling program at 26 sites representing the Bay of Quinte and nearshore habitats of Lake Ontario in August, 1990. Nearly 5,000 fish comprising twenty-four species were caught. Young-of-the-year walleye in the Bay of Quinte declined in abundance from 1989 by 70%. Young-of-the-year and yearling yellow perch have declined in abundance since 1988 in Lake Ontario and the Bay of Quinte.

Recommendations

1. Continue to use three replicate trawls at each sampling site.
2. Maintain the 12 Bay of Quinte sites as standards to be used in determining an annual YOY walleye index of abundance.
3. Conduct concurrent parallel trawls using outboard trawling gear and Research bottom trawling gear to resolve inconsistencies between YOY walleye indices of abundance as determined by the two gear types.
4. Verify the use of length frequency distribution data to determine yellow perch YOY and yearling abundance by comparison to scale and otolith age interpretation.
5. Search for additional trawling sites for Eastern Outlet Basin and Lake Ontario proper to increase the representativeness and precision of population abundance indices (e.g. for yellow perch).

Introduction

The Lake Ontario Fisheries Unit's outboard trawling program, initiated in 1988 (Bowlby 1989), is designed to index the abundance of "small" fish in the Bay of Quinte and the nearshore habitats of eastern Lake Ontario. Small fish include young-of-the-year (YOY), for species such as walleye, yellow perch and white perch, as well as small-bodied, prey species such as alewife, gizzard shad, trout-perch and spottail shiner.

The indices of abundance provided by the outboard trawling program should prove useful for predicting year-class strength and as early indicators of fish population response to stress from, for example, zebra mussel invasion.

The first two years of the outboard trawling program (1988 and 1989) focused on: 1) establishing suitable index trawling sites; 2) examining the influence of factors such as season and site depth on trawling catches; and 3) determining the optimal number of replicate tows at each site (Bowlby 1989). The conclusion reached was that three replicate trawls should be made at each site during August at a depth of 3 to 5 m and this design was adopted for the 1990 field season. Also implemented in 1990 was the biological sampling of several key species in the catch.

The objectives of this report are to: 1) summarize the 1990 catch results; 2) develop an index of abundance for YOY walleye in the Bay of Quinte in order to document year-to-year trends in year-class strength and to examine the precision of the abundance estimate given the current experimental trawling design; and 3) develop an index of abundance for YOY and yearling yellow perch in the Bay of Quinte and Lake Ontario based on their length distribution in the trawling catches.

Methods

Gear

The outboard trawling program utilizes a 6 m long trawl with 13 mm stretched mesh in the codend and with hardwood otter boards which are 0.6 m long and 0.3 m in height. The trawl is pulled behind a 6.1 m welded aluminum boat equipped with a 70 hp outboard motor and a knotmeter to regulate trawling speed.

Field Sampling Procedures

Trawling occurred in August across four major geographical areas. Three replicate trawls were made at each of 24 sites found suitable for trawling in previous years. Two replicate trawls were made at two additional, exploratory sites in the Bay of Quinte (Fig. 1, Table 1). All trawls were of 6 min duration at a speed of 4.3 km/hr and covered a distance of 430 m.

All fish were counted by species for each trawl catch. For some species, YOY (determined by size) and older fish were counted separately. Length tally information was recorded for up to 50 individuals of each species age-group at each site. Lengths and weights were measured for up to 100 individuals of each species age-group in each of four major geographic areas (Table 1). Lengths, weights, scales and otoliths were collected from up to 50 YOY walleye, YOY yellow perch, YOY white perch, and trout-perch from the Bay of Quinte.

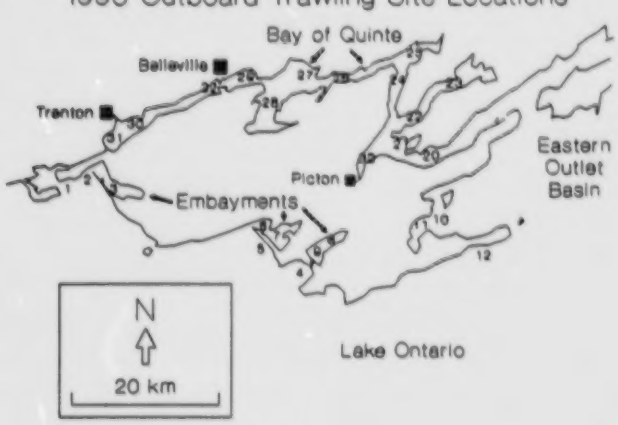

FIG. 1. 1990 Outboard trawling site locations.

Results of the biological sampling are not reported here. Scales and otoliths were archived for future age and growth studies.

Analysis

Two-factor analysis of variance (ANOVA) with unequal replication followed by the Student-Newman-Keuls Multiple Range Test (SNK test) was used to detect significant differences ($p = 0.05$) in mean catch-per-trawl (number per 430 m trawl) among years for YOY walleye in the Bay of Quinte and yellow perch age-classes (see below) in Lake Ontario and the Bay of Quinte. Both factors, year and site, were considered fixed (Model I ANOVA). Only sites where walleye or yellow perch had been captured in at least one year were included in the ANOVA's.

A method was developed to determine the precision of the YOY walleye abundance index and to examine the change in precision if the number of sites or the number of replicate trawls was varied from the current experimental design (12 sites and 3 replicate trawls per site). The SNK test uses critical values based on the q-distribution which are dependent upon the number of means in the range of means being tested and the error degrees of freedom for the ANOVA (Zar 1974). Calculated q-values are in turn dependent upon the magnitude of the difference between means for each year, the number of sites, the number of replicates, and the variance of the abundance index (error mean square from the ANOVA).

Substituting alternative q-values allowed calculation of the minimum detectable difference (precision) in YOY walleye catch-per-trawl for various combinations of numbers of sites and replicate trawls while holding the number of years and the error mean square from the ANOVA constant.

The relationship between mean and variance of the catch-per-trawl data was examined to determine appropriate transformations based on Taylor's Power Law (Green 1979). Transformations used on the catch data of several common species are shown in Table 2.

Inspection of yellow perch length frequency distribution data collected during the first three years of the outboard trawling program and a knowledge of their growth rate in Lake Ontario (Mathers 1989) suggested that it was possible to assign ages to YOY and yearling age-classes based on length (Fig. 2). A computer program ('MIX', MacDonald and Green 1988) was used to fit normal distributions to length frequency modes corresponding to mean length-at-age for YOY and yearling age-classes. Proportions of fish in 5 mm length intervals were assigned to each age-class (YOY, yearling, and all older age-classes combined). In this manner, a catch-per-trawl was determined for YOY, yearling, and older yellow perch.

Table 1. Trawling sites within each of the four major areas of Lake Ontario and the Bay of Quinte.

Area	Site name	Site number[a]
Lake Ontario	Middle Ground	1
	Barcovan	2
	Athol Bay	4
	Wellington Bay	5
	Big Sand Bay	12
Embayments	Wellers Bay	3
	West Lake (north)	6
	West Lake (south)	7
	East Lake (east)	8
	East Lake (west)	9
Eastern Outlet Basin	Morrison Point	10
	South Bay	11
Bay Of Quinte	Lyons Island	20
	Carnachan Island	21
	Ram Island	22
	Hay Bay	23
	Coles Wharf	24
	Deseronto	25
	Northport	26
	Hungry Bay	27
	Muscote Bay	28
	Belleville Island	29
	Baker Island	30
	Indian Island	31
	Picton Harbour[b]	32
	Belleville Cemetery[b]	33

[a] Site numbers are consistent with 1989 site numbers but not with those of 1988.

[b] New site in 1990.

Results and Discussion

Catch Summary

Twenty-four species were caught in 75 trawls at 26 sampling sites during the 1990 outboard trawling program (Table 3). Catches were summarized for each major geographic area as mean catch-per-trawl (Table 4).

Highest catches and greatest number of species occurred in the Bay of Quinte reflecting the Bay's high productivity and the greater trawling effort (14 sites) exerted here.

TABLE 2. Transformations used on catch data for several common species based on the relationship between mean and variance (Taylor's Power Law) and the discussion in Zar (Chapter 14, 1974).

Transformation	Species
Log_{10} (catch + 1)	Alewife, white perch (YOY), yellow perch
Square Root (catch + 0.5)	Spottail shiner, trout-perch, walleye

TABLE 3. Species caught during the 1990 outboard trawling program.

Common name	Scientific name
Alewife	*Alosa pseudoharengus*
Gizzard shad	*Dorosoma cepedianum*
Northern pike	*Esox lucius*
White sucker	*Catostomus commersoni*
Common carp	*Cyprinus carpio*
Golden shiner	*Notemigonus crysoleucas*
Emerald shiner	*Notropis atherinoides*
Spottail shiner	*Notropis hudsonius*
Bluntnose minnow	*Pimephales notatus*
Brown bullhead	*Ictalurus nebulosus*
American eel	*Anguilla rostrata*
Threespine stickleback	*Gasteroteus aculeatus*
Trout-perch	*Percopsis omiscomaycus*
White perch	*Morone americana*
White bass	*Morone chrysops*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*Micropterus salmoides*
Black crappie	*Pomoxis nigromaculatus*
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum vitreum*
Johnny darter	*Etheostoma nigrum*
Logperch	*Percina caprodes*

Only two trawling sites were sampled in the Eastern Outlet Basin area where bottom substrate suitable for trawling is scarce. Attempts to locate additional suitable trawling sites in this area and in Lake Ontario proper (currently 5 trawling sites) should continue in future years.

The five trawling sites located in Wellers Bay, East Lake, and West Lake were originally included in the outboard trawling program because of their potential to contribute fish production for Lake Ontario. Although the significance of such a contribution is still not known, the trawling series should be maintained in light of potential zebra mussel invasion impacts on the fish communities within these embayments of Lake Ontario.

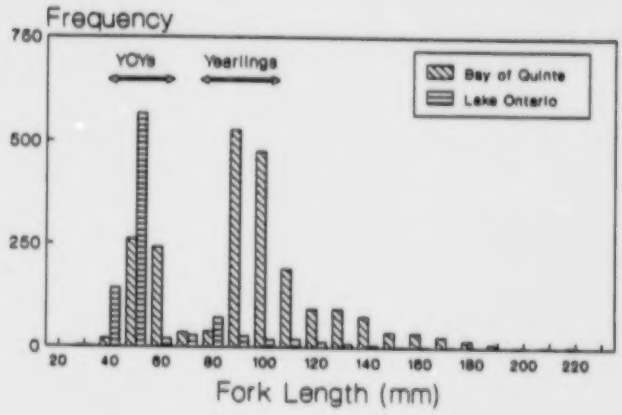

FIG. 2. Length frequency distribution of yellow perch captured during outboard trawling August, 1988.

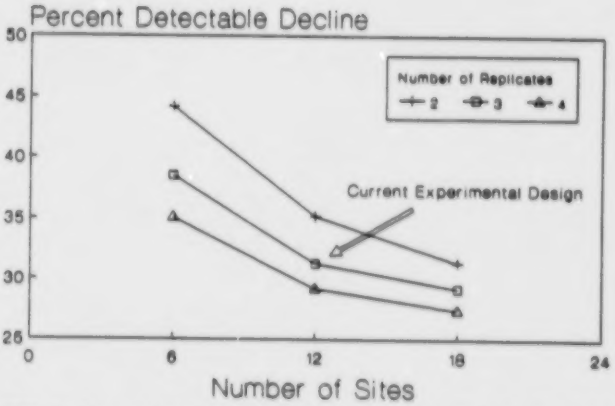

FIG. 3. Percent detectable decline in mean walleye catch-per-trawl for various combinations of numbers of sites and replicate trawls.

Indices of Abundance

Walleye

Trends in abundance

Young-of-the-year walleye abundance in the Bay of Quinte (Sites 20 to 31 inclusive, Table 1) was significantly lower (ANOVA, $p < .05$) in 1990 than in 1988 and 1989.

Precision of walleye abundance index

The observed decline in YOY walleye catch-per-trawl from 1989 to 1990 was 70% (based on untransformed means, Table 5). The minimum detectable decline from 1989 to 1990 based on the SNK test and the current experimental design was 32%. Figure 3 shows the minimum detectable decline in YOY walleye catch-per-trawl for several combinations of numbers of sites and replicate trawls while holding the number of years ($n = 3$) and the variance of the abundance index (error mean square from the ANOVA = 0.208) constant.

To date, the number of Bay of Quinte sites and the number of replicate trawls at each site have not remained constant (total number of trawls at Bay of Quinte sites were

TABLE 4. Mean catch-per-trawl for Lake Ontario, Embayments of Lake Ontario, Eastern Outlet Basin, and the Bay of Quinte during the 1990 outboard trawling program (Y = young-of-the-year; A = adult).

Species	Lake Ontario	Embayments	Eastern Outlet Basin	Bay of Quinte
Alewife	12.1	0.0	0.0	5.9
Gizzard shad	0.0	0.0	0.0	1.5
Northern pike	0.1	0.0	0.0	0.1
White sucker	0.0	0.0	0.0	0.1
Common carp	0.0	0.0	0.0	0.1
Golden shiner	0.0	0.0	0.0	0.1
Emerald shiner	0.2	0.0	0.0	0.0
Spottail shiner	9.3	3.5	0.0	8.4
Bluntnose minnow	0.0	3.5	0.0	0.0
Brown bullhead	0.2	0.5	0.3	0.3
American eel	0.0	0.0	0.0	0.2
Threespine stickleback	0.0	0.0	0.5	0.0
Trout-perch	0.0	0.0	0.0	5.9
White perch (A)	0.0	2.3	0.0	0.3
White perch (Y)	0.9	3.0	0.0	62.2
White bass (A)	0.0	0.0	0.0	0.3
Pumpkinseed	0.0	7.3	2.0	0.9
Bluegill	0.0	18.5	0.0	0.0
Smallmouth bass (A)	0.0	0.1	0.0	0.0
Largemouth bass (A)	0.0	0.1	0.0	0.0
Largemouth bass (Y)	0.0	0.1	0.0	0.0
Black crappie	0.0	4.2	0.0	0.2
Yellow perch (A)	0.5	2.4	0.0	3.2
Yellow perch (Y)	4.5	5.5	0.0	2.6
Walleye (A)	0.0	0.1	0.0	0.2
Walleye (Y)	0.0	0.3	0.0	0.6
Johnny darter	0.0	0.0	0.5	0.0
Logperch	0.0	0.1	0.0	0.0

27, 45 and 35 in 1988, 1989 and 1990, respectively). Based on Fig. 3, I recommend that the current trawling protocol (12 sites and 3 replicate trawls per site for a total of 36 trawls in the Bay of Quinte) be maintained in subsequent years.

Comparisons with Bay of Quinte research bottom trawls

The Research component of the Lake Ontario Fisheries Unit has conducted bottom trawling with much larger trawling gear on the Bay of Quinte since 1972. An index of YOY walleye abundance based on catches at three sites, Conway, Hay Bay and Big Bay, is currently used in the Lake Ontario walleye harvest management model (Bowlby and Mathers 1989a). The outboard trawling program provides an alternative index of walleye year-class strength which is based on replicate samples taken at 12 sites distributed throughout the Bay of Quinte and is therefore thought to be both more representative and precise.

Comparison of YOY walleye indices of abundance provided by the two programs for the two years of overlap (1988 and 1990) indicate inconsistent results (Fig. 4). The 1990 Research bottom trawl index of walleye abundance was the highest ever recorded (16.0 YOY walleye per trawl) but was influenced by exceptionally high catches at the Hay Bay Site (40.7 per trawl). Catches at the Conway (4.2 per trawl) and Big Bay (3.0 per trawl) sites were similar to 1988 levels.

TABLE 5. Mean catch-per-trawl (transformed data; untransformed means in parentheses) for several common Bay of Quinte species. Values with the same letter are not significantly different ($p > .05$).

	Year		
Species	1988	1989	1990
Walleye (YOY)	1.609 A (2.089)	1.538 A (1.865)	1.032 B (0.565)
Alewife	0.136 A (0.370)	0.126 A (0.337)	0.368 B (1.336)
Spottail shiner	3.047 A (8.284)	2.369 A (4.612)	2.572 A (5.615)
Trout-perch	3.707 A (12.742)	4.175 A (16.431)	1.999 B (2.996)
White perch (YOY)	1.208 A (15.144)	0.736 B (4.445)	1.202 A (14.922)

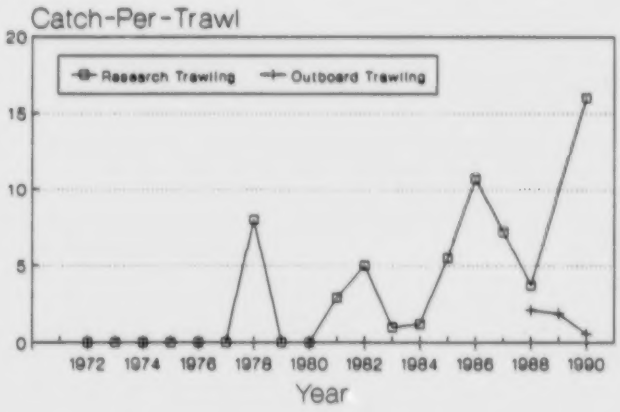

FIG. 4. Mean YOY walleye catch-per-trawl in the Bay of Quinte, 1972 to 1990.

Large numbers of YOY walleye were also caught at Foresters Island (18.0 per trawl) but this Research bottom trawl site is not included in the YOY walleye index of abundance. The wide variation observed among the Research trawling sites emphasizes the need to sample more locations if results are to be easily interpreted. The relative contribution of various spawning areas to the walleye population in the Bay of Quinte as a whole warrents investigation but can only be addressed by sampling a large number of sites. More years of program overlap are necessary to evaluate the relative merits of the YOY walleye indices provided by the two programs. Concurrent parallel trawling at one or more sites would help sort out the differences in catch results observed to date.

In the meantime, I recommend that managers continue to use the Research index of walleye year-class strength given that the index is highly correlated with mark-recapture

TABLE 6. Yellow perch mean catch-per-trawl (log transformed data; untransformed means in parentheses) for YOY, yearling, and older age classes combined in Lake Ontario and the Bay of Quinte. Values with the same letter are not significantly different ($p > .05$).

Age Group	1988	1989	1990
Lake Ontario sites			
YOY	1.036 A (9.864)	0.963 A (8.183)	0.483 A (2.041)
Yearlings	0.563 A (2.656)	0.000 B (0.000)	0.083 B (0.211)
Older	0.366 A (1.323)	0.000 B (0.000)	0.000 B (0.000)
Bay of Quinte sites			
YOY	0.855 A (6.161)	0.752 A (4.649)	0.312 B (1.051)
Yearlings	1.180 A (14.136)	0.502 B (2.177)	0.201 C (0.589)
Adults	0.848 A (6.047)	0.533 B (2.412)	0.137 C (0.371)

population estimates for 2 yr-old walleye of the same year-class (Bowlby and Mathers 1989b). However, management decisions should be conservative given the results of the 1990 outboard trawling program and the influence of a single site on the 1990 Research index of YOY walleye abundance.

Yellow Perch

Trends in abundance

All yellow perch age-groups declined in abundance from 1988 to 1990 in Lake Ontario (sites 1, 2, 4 and 5) and the Bay of Quinte (sites 21 to 31 inclusive, Table 6). Yearling yellow perch in the Bay of Quinte were particularly abundant in 1988. Catches of yellow perch older than yearlings were generally low, especially for Lake Ontario.

The outboard trawling program appears to provide good indices of abundance for YOY and yearling yellow perch but not for older age-classes. More sites should be trawled on Lake Ontario to increase sample size and precision of abundance estimates.

Other Species

Comparisons of annual indices of abundance (using the same Bay of Quinte sites used for the YOY walleye index of abundance) for several common species are shown in Table 5.

Acknowledgements

Thanks to the outboard trawling field crew, Wayne Miller, Kim Collins and Shane Lockwood. Thanks to Kelly Sarley for data entry, Tom Stewart, Alastair Mathers, Steve Kerr and Phil Smith for reviewing the manuscript, Carol Ward for copy editing and Linda Balsillie for publishing.

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Smelt Abundance And Growth In Western Lake Ontario

Alastair Mathers

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Lake Ontario Fisheries Unit 1990 Annual Report, LOA 91.1 (Chapter 3)

The abundance of smelt, based on bottom trawling, in western Lake Ontario over the years 1981-1990 was estimated at between 0.3 and 1.9 billion. Prior to 1990 the yearling population has cycled with peaks every two to three years. The yearling population during 1990 was estimated at 155 million fish. This represents the third year of decline in yearling numbers since the peak in 1987. The adult population (150 million fish aged 2 yr and older) was the lowest observed since the survey's initiation in 1981. Adult survival rates have remained low for the last two years. Growth of all age groups and weight of yearling smelt in 1990 was also low relative to previous years.

Recommendations:

1. Continue to use bottom trawls to monitor smelt in western Lake Ontario.
2. Continue to develop prey fish stock assessment techniques suitable for all of the Canadian waters of Lake Ontario.
3. Collaborate with American biologists to reconcile differences in methodology such as aging and confirm the observed differences in growth and abundance.
4. The smelt population is currently small and should not be relied on to provide a good alternate food source for salmonids if the alewife abundance declines.

Introduction

Studies of salmonids diets in both U.S. waters (Brandt 1986) and Canadian waters of Lake Ontario (Plante et al. 1991) have shown that in general rainbow smelt (*Osmerus mordax*) are the second most important prey item relative to the alewife (*Alosa pseudoharengus*). Smelt are particularly important to lake trout and to young chinook salmon. Also, smelt may be more important to the diet of all salmonids in years of low alewife abundance. This is supported by O' Gorman et al. (1987) who found that survival of adult smelt is reduced in years of low alewife abundance. Ecologically sound management of the Lake Ontario salmonid fisheries requires that the status of smelt stocks continue to be assessed.

In the spring of 1978, the U.S. Fish and Wildlife Service (USFWS) initiated a bottom trawl sampling program to assess abundance of smelt and alewife in U.S. waters (O' Gorman et al. 1991). Beginning in 1981, smelt were sampled from bottom trawls in Canadian waters during juvenile lake trout assessment conducted jointly in August by the USFWS, New York Department of Environmental Conservation (NYDEC), and Ontario Ministry of Natural Resources (OMNR). Cooperative spring (June) bottom trawling for smelt in Canadian waters, independent of the juvenile lake trout assessment, began in 1986.

The purpose of this report is to update yearling abundance, adult abundance and growth of smelt in Canadian waters of western Lake Ontario; compare these data to information from the U.S. bottom trawling surveys; and discuss factors affecting abundance, survival and growth.

Methods for Fish Sampling and Abundance Calculations

In early August of 1981-85, the USFWS Research Vessel Kaho bottom trawled along three principal transects in western Lake Ontario; Niagara, Hamilton, and Toronto (Fig. 1). At each site, trawling was done at 5 m depth intervals starting at 15 m to 20 m to a maximum of 55 m. A severe storm during the western Lake Ontario trawling in 1983 drastically altered local smelt distributions (Stewart and Oliver 1989). Therefore, 1983 western Lake Ontario data were not used in this summary.

From 1986-90, sampling was conducted in June at approximately the same locations with the addition of an 8 m site and several sites deeper than 55 m. To accom-

FIG. 1. Map of western Lake Ontario. Bottom trawls were taken within shaded areas at Niagara, Hamilton, and Toronto.

modate differences in sampling depths among years, we derived estimates of abundance for bottom areas common to all years surveyed (10 m to 50 m). Catches were stratified into bottom areas of 10 m to 20 m, 20 m to 30 m, 30 m to 40 m and 40 m to 50 m. Each year's abundance was the summation over all areas of the average catch/10 min tow in each depth stratum times the number of hectares in each stratum, divided by the area trawled (0.73 ha/10 min tow).

During 1990, twenty-one of the normal twenty-seven trawls were completed. Five of the trawls missed were at the Toronto transect and one was at the Hamilton transect. To ensure a reliable comparison among years, missing catches of yearlings were estimated by regression derived from the 1986-89 data. It was not necessary to correct adult catches as analysis of variance of the 1986-89 data indicated no difference in catches among transects. Missing yearling catches at Toronto were estimated from Hamilton catches ($r^2 = 0.885$, $p = 0.11$). Missing yearling catches at Hamilton were estimated from the sum of Toronto and Niagara catches ($r^2 = 0.948$, $p = 0.05$).

Methods for Age Composition and Growth of Smelt

A random sample of smelt were measured for length from each depth contour sampled. Length, weight, sex, and aging material were taken from a length stratified subsample of approximately 200-400 individuals per yr. Fish were aged by scales from 1981-85, and from pectoral fin ray sections from 1986-90. No fish were aged from the sampling in 1984, so an age-length key determined from data collected in combined 1983, 1985, and 1986 were used to estimate age composition for 1984.

Population length frequency distributions were derived by combining length samples, weighted by catch-per-10 min trawl, for each depth strata separately. A standard age-length key was then applied to determine the age composition at each depth strata. Ages were then weighted by the area of the depth strata and the area trawled, then the depth strata were combined, producing population estimates for each age group.

Length and weight at age were compared among years. Only data collected after 1985 were considered in this analysis since they were collected at the same time of year. Survival was calculated by dividing pooled abundance estimates of fish aged 4 yr and older in year T + 1 by the pooled abundance of fish aged 3 yr and older in year T.

Yearling Abundance

The estimated abundance of yearling smelt in 1990 was 155 million fish (10 m to 50 m depth)(Fig. 2). The yearling abundance observed this year is relatively low but is similar to those observed in 1981, 1983, and 1984. In the past, yearling smelt abundances in both U.S. and Canadian waters of Lake Ontario have cycled with a 2 or 3 yr period (Mathers and Stewart 1990; O'Gorman et al. 1991). This year, being the third year of decline since the peak yearling abundance in 1987, does not fit the cyclical pattern.

In the past, abundance of yearling smelt in the western end has been strongly correlated with abundance in U.S. waters (Stewart and Oliver 1989). During 1990, the CUE of yearling smelt in U.S. waters was 188 fish per tow (O'Gorman et al. 1991). This is a decline from 1989, however the 2 yr cycle of peaks in yearling abundance appears to be continuing in U.S. waters.

Adult Abundance, Survival, and Recruitment

The abundance of adult smelt (aged 2 yr and older) observed in 1990 was 150 million fish (Fig. 2). This is the lowest adult abundance observed since this survey's initiation in 1981 and is the second year of decline since the peak in 1988. The abundance of adult smelt in the U.S. waters is also low relative to past surveys (O'Gorman et al. 1991).

Survival of fish aged 3 yr and older from 1989 to 1990 was very low (0.140). This result was also observed for 1988 to 1989 (Fig.3). I project that the adult stock in 1991 will be 129 million fish, even lower than it was in 1990. This prediction is influenced by the weak 1989 year-class (currently yearlings) and assumes that average mortality rates will be experienced.

No consistent stock-recruitment relationship is apparent for western Lake Ontario (Fig. 4). However, it should be noted that both strong (eg. 1981, 1984, and 1987) and weak year-classes (eg. 1989) were produced by small adult stocks (200 to 250 million fish). O'Gorman et al. (1987) suggest that the size of the adult stock does not appear to be an

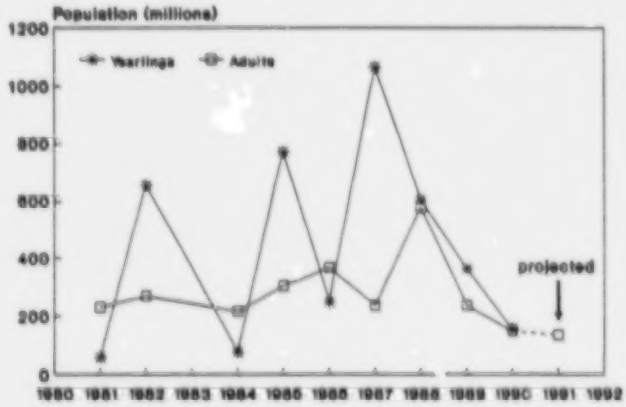

FIG. 2. Abundances of smelt, by age group, available to bottom trawls in western Lake Ontario areas of 10 m to 50 m depth. Age structure data for 1984 are estimated from age data in proximate years.

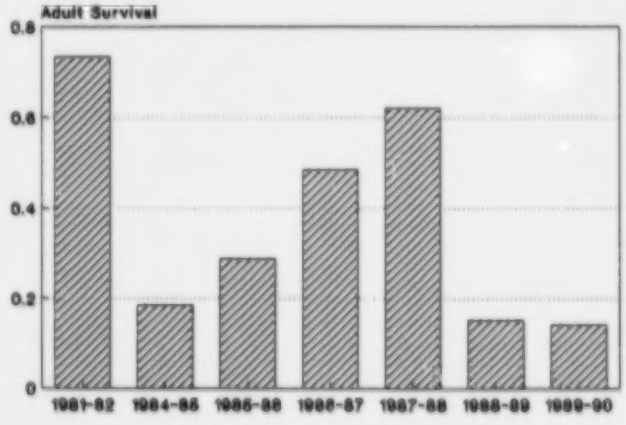

FIG. 3. The survival rate of adult smelt captured in trawls (10 m to 50 m water depth) in western Lake Ontario. Survival was calculated as abundance of ages 4 and older in year T + 1 divided by abundance of ages 3 and older in year T.

important factor affecting year-class strength. However, they did find that the size of the preceding year-class did have an effect on year-class strength. If this relationship applies there should be good numbers of yearlings in 1991.

Smelt are important to the diet of salmonids in Lake Ontario, although they generally occur in stomachs less frequently than alewife (Brandt 1986, Plante et al. 1991). It has been suggested that smelt could provide an alternate source of food should alewife populations decline. The current smelt population is very small and would not provide an adequate, long-term, alternate food source for salmon.

Size of Smelt

Smelt observed in western Lake Ontario during 1990 were among the smallest observed in recent surveys, with only 3.7 million fish (1.2% of total abundance) having a total length greater than or equal to 150 mm (Fig. 5). Data from individual age groups were compared between years with analysis of variance. There was no significant difference between the lengths of the 5 yr olds caught in different years ($F = 2.39$, $p = 0.056$). However, for all other age groups there were significant differences ($F > 4.27$, $n > 192$, $p < 0.002$) and Duncan multiple range tests suggest that the fish caught in 1990 were among the smallest for their age group (Fig. 6). O' Gorman et al. (1991) found that growth of smelt in U.S. waters during 1990 was slower than average for 2 and 3 yr olds but similar to recent years for the yearlings.

Similarly, analysis of covariance showed that, after correcting for differences in length, the weight of yearling smelt observed in 1990 was also among the lowest observed in this survey ($F = 11.06$, $n = 400$, $p = 0.0001$)(Fig. 7). This change in condition factor represents an 11% lower weight for a yearling smelt in 1990 relative to the 1986 to 1989 average. The weight of adult smelt (of a standard length) in 1990 was the lowest observed in this survey however the differences were not significant ($F = 1.39$, $n = 751$, $p = 0.237$). Overwinter survival of other fish species has been linked to their size (Shuter et al. 1980) and it is possible that the low condition of yearlings will lead to low survival.

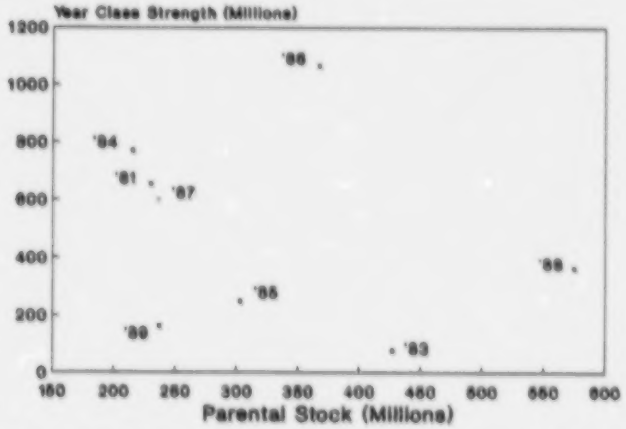

FIG. 4. The relationship between parental stock of smelt (aged 2 yr and older) and recruits (as shown by yearlings in the following year). Data are from trawls (10 m to 50 m water depth) in western Lake Ontario, 1981 to 1989. The year-class is shown beside each observation.

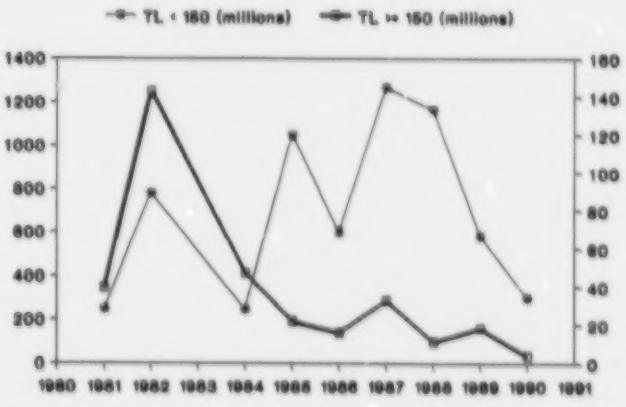

FIG. 5. Estimated abundance of large smelt (total length > = 150 mm, righthand Y axis) and small smelt (total length < 150 mm, lefthand Y axis) for the 10 m to 50 m depth strata sampled during the 1990 bottom trawl program in western Lake Ontario.

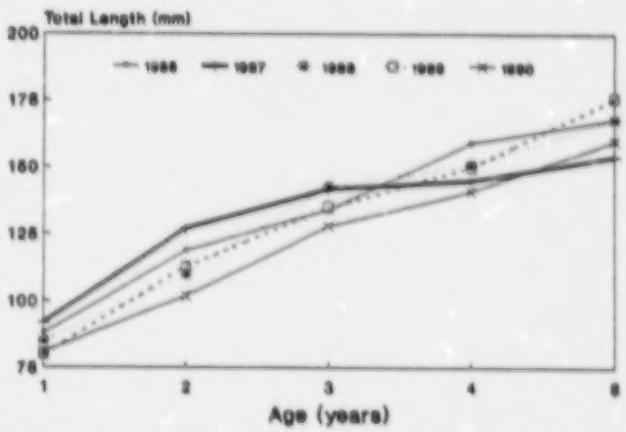

FIG. 6. Mean size of smelt, ages 1 to 5, caught during bottom trawling conducted during 1990 in western Lake Ontario.

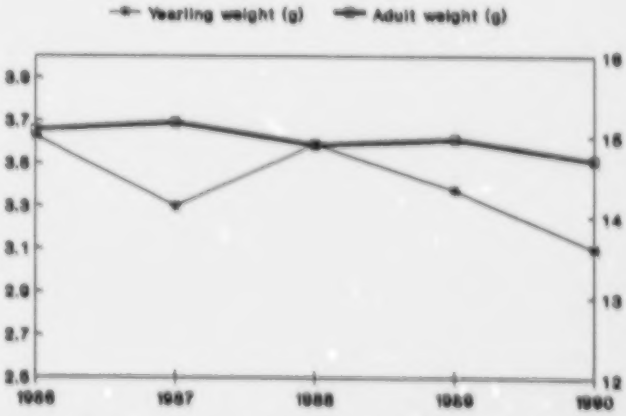

FIG. 7. Mean weight of standard sized yearling (lefthand Y axis) and adult smelt (righthand Y axis) in western Lake Ontario estimated by analysis of covariance.

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Stocking Assessment of Brown Trout, Rainbow Trout, and Coho Salmon in the Boat Fishery of Western Lake Ontario

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Stocking return information was calculated from fin clip and harvest data that was collected during angler interviews for the boat fishery in the western and central basins of Lake Ontario from 1983 to 1989. In 1989, coho salmon and rainbow trout stocked by the Province of Ontario accounted for 2.3% and 2.2% of the harvest, respectively, in the western Lake Ontario boat fishery. Brown trout stocked by Ontario contributed only 0.5% of the harvest. Chinook salmon dominate the harvest and these species are of lesser importance. The percentage of stocked Ontario coho and rainbow trout that were returned in the western Lake Ontario boat harvest, was about 2% each . The return rate for brown trout was only 1%. These rates are biased low because of fin clip regeneration and errors. As well, this portion of the fishery represents only 47% of the salmonid harvest on the Ontario side of Lake Ontario. Adding the harvest from New York waters, the Kingston basin, shorelines and streams would likely double these return rates. In 1989, 25% of coho salmon, 7% of rainbow trout and 36% of brown trout observed in the boat harvest were stocked by Ontario. These numbers are sensitive to stocking by New York and natural reproduction, and must be interpreted with care. Natural reproduction has been estimated at 22% for rainbow trout, 56% for coho salmon and 6% for brown trout. The offspring from brown trout stocked in Lake Ontario do not appear to have much tendency to smolt, but rather likely contribute to stream resident populations. In general, fall fingerling and spring yearling coho salmon survive equally well. Also, there were no significant differences in survival of coho salmon stocked in the the Credit River, Martindale Pond, and Bronte Creek.

Recommendations:

1. Stock fall fingerlings of coho salmon rather than spring yearlings into habitats that are underutilized by native salmonids, up to the carrying capacity of the receiving streams. If stocking above the carrying capacity is desired then stock during spring when the fish are ready to smolt.
2. Compare fall fingerling vs spring yearling stocking for brown trout and rainbow trout.
3. Do not use pectoral fin clips for marking fish.
4. Record regeneration and error rates for fin clips in Fish Culture Stations.
5. Evaluate the stocking returns from the shore fishery, stream fishery, and Kingston basin boat fishery.
6. Incorporate data for Ontario returns from New York angler surveys.
7. Verify and refine expansions used to calculate the boat fishery harvest.
8. If natural reproduction increases then decreases stocking by an equivalent amount to maintain current steady state between predator and prey fish in Lake Ontario.

Introduction

Virtually all brown trout, rainbow trout and coho salmon stocked by the Province of Ontario, into Lake Ontario, receive fin clips for the assessment of fish stocking success. The choice of fin clips has been made to discriminate between year-classes, stocking locations, or age of stocking (i.e. fall fingerlings (FF) and spring yearlings (SY)). This report summarizes fin clip returns of Ontario stocked brown trout, rainbow trout, and coho salmon from the Ontario boat angling fishery in western Lake Ontario. Assessment of stocked lake trout has received considerable attention elsewhere as a result of attempts to rehabilitate this species in Lake Ontario (Schaner 1990; Schneider et al. 1990). The purpose of this summary is to identify gaps in stocking assessment information and to provide information for discussion about future stocking practices in Lake Ontario.

Methods

Estimation of Catch

Fin clip information was collected from angler-caught fish during creel interviews at access points in the western and central basins of Lake Ontario from 1983 to 1989 (e.g. Stewart et al. 1990). The information collected at these interviews was used to estimate the total catch by species for anglers who launched their boats at access points. Expansions were made to estimate catch at unsurveyed access points. In later years (1985 to 1989), trailer counts were used to make these expansions (e.g. Daniels and Savoie 1986). For 1983 and 1984 only the Toronto Star Derby was surveyed, and so expansions were based on the ratio of catch by species in 1985 between the Toronto Star Derby and the Oshawa-Whitby Derby plus the St. Catharines Derby (Table 1). Also, the 1985 expansion (1.45: Daniels and Savoie 1986) for unsurveyed time periods (between derbies) was used for 1983 and 1984. This assumes that the rate of growth of these derbies from 1983 to 1985 was similar. Refinements to this expansion should include the relative rates of growth of these derbies.

The fishery off Brighton and Wellington was examined only in 1987 and 1989. For 1988, the mean catch in 1987 and 1989 was used. For 1983 to 1987, we assumed that the fishery doubled each year (D. Montgomery, pers. comm.) and extrapolated backward from 1987.

Marina-based private and charter boats were surveyed in 1989 (Stewart et al. 1990), and the ratio of access angler catch to marina-based catch in 1989 (Table 1) was used to expand catch by species to the whole boat fishery for 1983 to 1988. An assumption here was that the rate of growth in the access- based fishery was similar to the rate of growth for the marina- based fishery.

These expansions are based on a number of reasonable assumptions that have not been tested, but that can be tested for future use of this data. In particular, our charter boat survey database, information on derbies, and information on the rate of marina expansion should be used to test and refine these expansions.

TABLE 1. Expansion factors for harvest estimates in the Lake Ontario boat fishery. The marina/charter expansion represents the size of the total boat fishery compared to size of the access boat fishery. The derby expansion is the ratio of the St. Catharines derby plus Oshawa-Whitby derby to the Toronto Star Derby.

Species	Marina/charter	Derby
Coho salmon	3.21	1.23
Rainbow trout	3.64	0.21
Brown trout	1.81	4.11

Fin Clips

Fin clips were used on brown trout, rainbow trout, and coho salmon to identify fish stocked by Ontario and to provide information on age and stocking location (Table 2). Clips and fish size were used to assign an age. Incorrect clips and what appeared to be clips with greater than 50% regeneration were assumed to be unclipped or of unknown origin (New York or Ontario). Many unscheduled pectoral fin clips had more than 50% regeneration. Since hatchery fish experience more wear on pectoral fins (B. Marchant, unpubl. data; K. Wood, pers. comm.) we assumed these were not real clips but resulted from hatchery or spawning wear. Values of percentage of Ontario clips may be lower here than values reported elsewhere for the same data because other workers have assumed that all right-sided clips with $< 90\%$ regeneration were Ontario stocked fish, whether corresponding to planned clip schedule or not.

The potential for bias resulting from these clipping problems is a particularly great concern for comparison of paired stockings (e.g. FF vs SY). These biases were examined but were not great enough to affect the interpretations here (see below).

The numbers of fin-clipped fish stocked by Ontario include only the fish stocked into western basin tributaries (Table 2). Kingston basin stockings of brown trout were excluded because we have little information on harvest in this basin. For calculating stocking returns all fall fingerlings were labelled as yearling equivalents, and were treated as if they had been stocked the following spring. Each cohort was labelled as the year stocked as yearling equivalents (i.e. fish stocked as finglerlings were treated in the calculations as if they had been stocked the following year, as yearlings), except for FF vs SY comparisons.

TABLE 2. Number of fin clipped fish stocked as yearling equivalents in western Lake Ontario tributaries.

Year	Coho salmon		Rainbow trout		Brown trout	
	Number stocked	Fin clip	Number stocked	Fin clip	Number stocked	Fin clip
1982	141,533	RV,RP,Ad	7,100	RP		
1983	142,000	RV,RP,Ad	88,500	RP		
1984	181,405	RP,Ad-RP,Ad	110,000	RV	96,408	Ad-RV
1985	163,772	RV,Ad	106,231	Ad	105,538	RP
1986	183,196	RV,RP	200,000	RV	241,300	Ad
1987	277,424	RV,Ad,Ad-RP	306,060	Ad	201,513	RV
1988	335,899	RV,Ad,Ad-RV	264,140	RV	304,958	RP,Ad-RV

Results

Stocking Returns to Harvest

From 1983 to 1989, the harvest of coho salmon and brown trout showed no consistent trend (Fig. 1). Recent increases in the stocking of these species by Ontario were not followed by increases in harvest. This may be due to earlier closing dates of the Toronto Star Derby. These species are most abundant in the catch during spring and September when the Star Derby does not run. However, the Star Derby participants account for much of the effort in the fishery. In contrast, rainbow trout catches peak in mid-summer when the Star Derby runs. The harvest of rainbow trout tripled over this period. This trend is consistent with the introduction of wild Ganaraska strain for stocking, with increased stocking by Ontario, with increases in "steelhead" stocking by New York, and with increases in the rate of natural reproduction in north shore streams such as the Ganaraska River and Wilmot Creek (D. Bell, pers. comm.).

In 1989, coho salmon and rainbow trout stocked by Ontario contributed almost equal numbers to the western boat fishery and brown trout contributed considerably less (Table 3). In total, brown trout, rainbow trout and coho salmon stocked by Ontario contributed towards 6.0% of the boat harvest. The great decline in importance of coho after 1983 (Table 3) reflects a shift in angler interest toward the increasing populations of chinook salmon.

Our sample sizes for observed clips were rather small prior to 1986 (Table 4). More recent expansions in our angler survey has resulted in sampling about 100 Ontario-clipped coho salmon, about 50 Ontario-clipped rainbow trout, and similar numbers of Ontario-clipped brown trout.

These clips have indicated that in 1989, 25% of the coho salmon fishery, 7% of the rainbow trout fishery, and 36% of the brown trout fishery are based on fish stocked by Ontario (Table 5). For brown trout and rainbow trout these percentages have increased steadily as more stocked cohorts entered the fishery. These are the numbers which have been calculated for stock assessment purposes in previous LOFU Annual Reports (e.g. Stewart et al. 1990) mainly because information presented here was not available. However, I caution the use of these percentages because they are easy to misinterpret. These percentages are confounded by changes in natural reproduction and New York stocking practices as well as improvements in the quality of hatchery product or changes in the behaviour of the fishery. For instance, improvements in the survival of Ontario-stocked fish could be masked by increased natural reproduction or increased survival of fish stocked by New York.

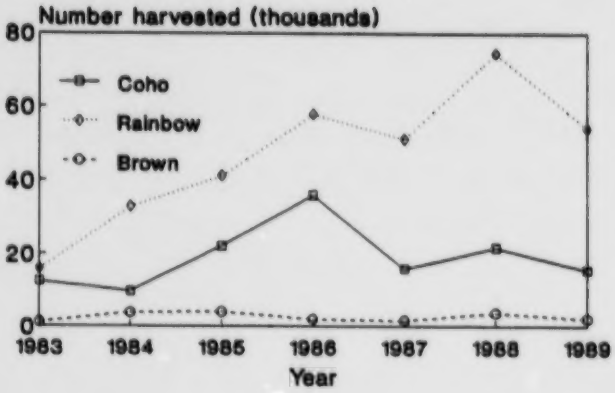

FIG. 1. The harvest of coho, rainbow and brown trout in the western boat angling fishery in Lake Ontario.

Brown trout and rainbow trout are in the fishery for 5 yr after being stocked, whereas coho salmon are in the fishery for only 2 yr after being stocked (Table 4). Accordingly, a complete assessment of brown trout and rainbow trout takes 5 yr of observations to calculate a rate of return to the fishery.

The rate of return for coho salmon averaged 2.3% for the 1982 to 1988 cohorts. This rate represents the stocked fish that are harvested in the western boat fishery as a percent of what was stocked by Ontario in the western basin. The rate of return of coho salmon was highly variable among cohorts (Table 6). Years of high return rates for coho salmon may have been due to early staging of the spawning river mouths or later derbies.

The 1985 cohort of rainbow trout had a return rate of 1.9% (Table 6). However, only the 1984 cohort is completely through the fishery (Table 4). Only Ganaraska strain rainbow trout were considered here. Stocking of this strain began in 1984. In the previous year, rainbow trout stocked by Ontario were not marked before stocking.

Three brown trout cohorts are through the fishery and they have shown a steady increase in the rate of return up to 0.9% for the 1985 cohort. This was a new species for our hatchery system and these increases in return rate may

TABLE 3. Estimated western boat harvest of coho, rainbows, and browns stocked into Lake Ontario by Ontario for the years 1983 to 1989. The number below in parenthesis indicates the percent of the total salmonid harvest including chinook salmon.

Species	1983	1984	1985	1986	1987	1988	1989
Coho salmon	6863	1282	2461	8672	2472	4062	3849
	(15.5)	(1.7)	(1.6)	(3.6)	(1.3)	(2.1)	(2.3)
Rainbow trout			302	1863	1310	2388	3662
			(0.2)	(0.8)	(0.7)	(1.3)	(2.2)
Brown trout	80	140	442	371	696	1640	782
	(0.2)	(0.2)	(0.3)	(0.2)	(0.4)	(0.9)	(0.5)

TABLE 4. Number of Ontario clipped fish observed by cohort (year stocked as yearling equivalent) in angler access surveys in Lake Ontario for the years 1983 to 1989.

Cohort	Year Observed							
	1983	1984	1985	1986	1987	1988	1989	Total
Coho salmon								
1982	129	0	0	0	0	0	0	129
1983	4	11	0	0	0	0	0	15
1984	0	3	15	0	0	0	0	18
1985	0	0	3	94	0	0	0	97
1986	0	0	0	2	60	0	0	62
1987	0	0	0	0	1	99	0	100
1988	0	0	0	0	0	2	88	90
1989	0	0	0	0	0	0	3	3
Total	133	14	18	96	61	101	91	514
Rainbow trout								
1984			3	20	5	1	1	30
1985			0	8	13	14	2	37
1986			0	0	6	22	13	41
1987			0	0	0	12	13	25
1988			0	0	0	0	26	26
Total			3	28	24	49	55	159
Brown trout								
1983	1	0	0	0	0	0	0	1
1984	0	1	0	1	2	1	0	5
1985	0	0	2	4	6	11	0	23
1986	0	0	0	1	25	37	6	69
1987	0	0	0	0	1	48	17	66
1988	0	0	0	0	0	2	16	18
Total	1	1	2	6	34	99	39	182

TABLE 5. Percent contribution of fish stocked by Ontario to the harvest by the western boat fishery in Lake Ontario for the years 1983 to 1989.

Species	1983	1984	1985	1986	1987	1988	1989
Coho salmon	55.2	13.3	11.1	24.1	15.5	18.7	24.7
Rainbow trout			0.7	3.2	2.6	3.2	6.8
Brown trout	7.1	3.7	11.1	18.8	41.5	44.0	36.4

TABLE 6. Rate of return of fish stocked by Ontario that are harvested in the western Lake Ontario boat fishery as a percentage of what was stocked. Note that these numbers are presented on a cohort basis. Thus for rainbow trout and brown trout, the more recent cohorts are still being harvested and these numbers will increase.

Cohort	Coho salmon	Rainbow trout	Brown trout
1982	4.70		
1983	0.85		0.09
1984	1.28	1.84	0.27
1985	5.44	1.94	0.94
1986	1.43	1.13	0.54
1987	1.45	0.47	0.57
1988	1.13	0.66	0.12

reflect improvements in hatchery and stocking practices associated with learning the specific requirements of a new species, as well as increased targeting by the fishery.

Natural Reproduction

Casselman et al. (1990) are currently developing techniques using scales and otoliths for discriminating between wild (naturally produced) and hatchery fish. He found that 34% of the unmarked rainbow trout in the 1989 angler survey were wild. Combining this with the 63% proportion of unmarked rainbow trout in the survey (Stewart et al. 1990), 22% of the rainbow trout in the 1989 fishery were concluded to come from natural reproduction (Fig. 2).

The proportion of wild brown trout and coho salmon in the fishery was estimated from expected proportion of Ontario and New York fish in the creel, based on stocking proportions, assuming even distribution of Ontario and New York fish. Using this technique, 56% of coho salmon and 6% of brown trout in the angler survey were estimated to be wild (Fig. 2). Reduced movement from stocking locations would tend to overestimate the proportion of New York fish and underestimate the amount of natural reproduction. On the other hand, fin clipping errors and fin regeneration would cause an overestimate of natural reproduction.

Coho Salmon Stocking Experiments

Fall Fingerlings vs Spring Yearlings

There have been three separate experiments testing the performance of fall fingerlings (FF) and spring yearlings (SY) using angling survey data for the test. These experiments used three different locations: Bronte Creek, Credit River, and Martindale Pond. There were no significant differences in return from the proportion stocked between FF and SY at these locations (Table 7). Bias due to differential regeneration of adipose and paired fins has not likely affected the statistical significance of these results, because regeneration is felt to be less than 20% on the paired fins which is less than required to change these results.

Stewart (1989) showed that FF returned to the Credit River in higher proportion than expected in 1988, but Plante and Bowlby (1990) showed that SY returned in higher numbers than expected in 1989 (Table 8). Although these differences in return rate were statistically significant, none of the treatments would be considered a biological failure since returns were good from all treatments. Regeneration of paired fins is not an issue here due to few observations of unclipped fish.

Stocking Location Experiments

There have been six experiments testing the performance of SY at the following stocking locations: Oakville Creek, Bronte Creek, Credit River, and Martindale Pond. There were no significant differences in return from the proportion stocked among these locations (Table 9). For the same reasons as above, regeneration would not have affected the statistical significance of the results.

Discussion

Clipping Errors and Clip Regeneration

The clip returns presented here are low due to missed clips, incorrect clips and partial clips which tend to regenerate. A request for clipping error and regeneration data from Fish Culture Stations (FCS) producing fish for Lake Ontario provided some information, but insufficient to adjust the return data to account for errors and regeneration rates. All of the FCSs queried felt that the current error rates (missed or incorrect clips) were quite low (< 2%), and moreover, this condition was written into

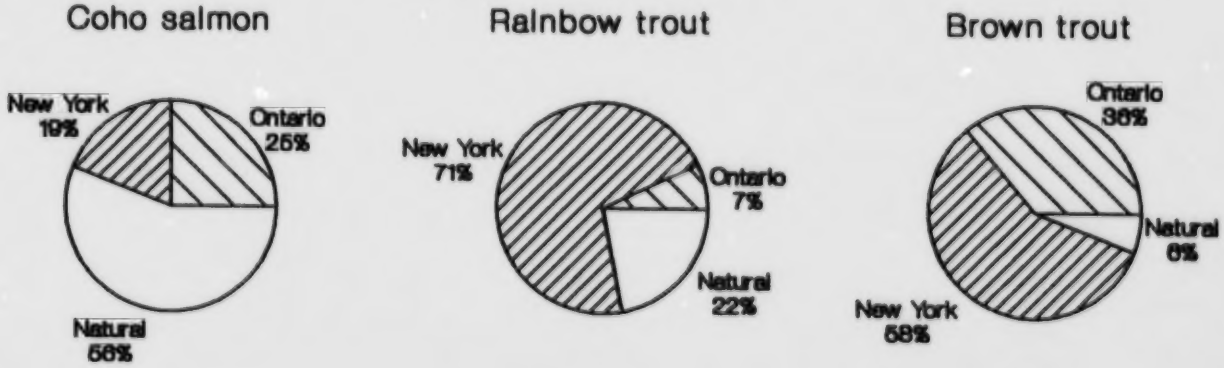

FIG. 2. Origin of fish harvested in western Lake Ontario boat fishery during 1989.

TABLE 7. G-test for comparison of the number of FF and SY coho salmon observed in the boat angler harvest in western Lake Ontario.

Year stocked	Age	Stocking location	Number stocked	Number observed	G	P
1981	FF	Bronte	29500	21	0.02	0.8930
1982	SY	Bronte	25085	19		
1983	FF	Martindale	75800	9	0.05	.8183
1984	SY	Martindale	31839	3		
1987	FF	Credit, Bronte, Martindale	128800	33	0.08	.7709
1988	SY	Credit, Bronte, Martindale	207099	58		

TABLE 8. G-test for comparison of the number of FF and SY coho salmon observed in the Credit River egg collection (Stewart 1989; Plante and Bowlby 1990).

Year stocked	Age	Stocking location	Number stocked	Number observed	G	P
1986	FF	Credit	17224	96	14.50[a]	< 0.001
1987	SY	Credit	48418	153		
1987	FF	Credit	66337	99	12.73	< 0.01
1988	SY	Credit	51935	125		

[a]This hypothesis assumes that 72,538 BKD infected fish died before reaching the fishery. If the BKD infected fish survived then FF out performed SY greater than indicated here.

TABLE 9. G-test for comparison of the number of coho salmon by stocking location observed in the boat angler harvest in western Lake Ontario.

Year stocked	Age	Stocking location	Number stocked	Number observed	G	P
1982	SY	Bronte	25085	19	0.78	0.3759
1982	SY	Credit, Martindale	86948	89		
1983	SY	Bronte	24400	6	2.92	0.232
1983	SY	Credit	93200	5		
1983	SY	Martindale	24400	3		
1984	SY	Martindale	31839	3	0.1	0.7509
1984	SY	Credit	73766	5		
1985	SY	Credit	71172	30	1.47	0.2249
1985	SY	Bronte, Martindale, Oakville	92600	57		
1986	SY	Credit	90493	36	0.95	0.3305
1986	SY	Bronte, Martindale	92702	26		
1988	SY	Credit	51935	21	1.72	0.1894
1988	SY	Bronte, Martindale	155164	37		

recent contracts for clipping. Data provided by Codrington FCS and Ringwood FCS suggest that these rates are actually less than 1%. However, Ringwood also provided some older information that suggested historical regeneration rates and error rates likely were between 16 and 55% for right ventral (RV) clips, but only 1% for Adipose (Ad) clips on coho salmon. To obtain more precise regeneration rates on these RV clips would have required a more detailed description or coding of the clip problem.

It is unfortunate that information on clip regeneration was unavailable, especially considering that Ad clips are unlikely to regenerate at the same rate as RV clips. If these regeneration rates are not accounted for then the resulting bias will skew interpretation of stocking experiments (e.g. FF vs SY). Here, the bias was examined for the coho stocking experiments, and although it did exist, it did not likely affect the overall interpretation of the results.

The other problem with unknown regeneration rates was that return rates were biased low. The fish from Ontario FCSs might be performing better than the results here may indicate. A relatively simple examination of a subset of clipped fish should be performed some time after clipping to determine regeneration rates for each lot of fish or group of similar lots.

A number of pectoral clips were observed on rainbow trout, although that clip was not used. Further to this, Ringwood FCS provided data showing that 89% of the coho examined had significant pectoral fin erosion, and Kevin Wood (pers. comm.) also indicated that brown trout are quite susceptible to excessive pectoral fin erosion. Thus, any system of recording partial fin regeneration might incorrectly include such eroded fins as a clip. The use of pectoral fin clips should be avoided since interpretation of such data might be misleading.

Other Fishery Components

Current assessment programs fail to account for the stream fishery, the shore fishery, or the Kingston basin boat fishery. These components of the fishery have a poorly understood impact on stocked fish. Considerable anecdotal information and some data suggest that significant stream and shore fisheries are created by stocking. From this rather sparse information Savoie and Bowlby (1991) have estimated that the western boat fishery accounts for only 47% of the salmonids harvested on the Ontario side of Lake Ontario. For example, brown trout occupy the near shore zone and anecdotal information indicates it is abundant in spring and fall shore angler catches. An angler survey during fall 1986 at the mouth of the Ganaraska River estimated that 174 brown trout were harvested (D. Bell, unpubl. data) and most of these fish were likely stocked previously at the mouth of the Ganaraska. Another angler survey from December 15, 1988 to April 30, 1989, estimated that 1747 brown trout were harvested and 70% of these were stocked by Ontario (Schaap et al. 1989). The harvest from these two fishery components alone triples the 1989 boat harvest of brown trout stocked by Ontario (Table 3). There are other highly visible stream and shoreline fisheries based almost totally on fish stocked by Ontario. Since natural reproduction is poor or non existent in some stocked streams, these fisheries would be drastically reduced without stocking (e.g. Credit River, Rouge River, Port Dalhousie).

The Kingston basin fishery is not considered here, nor are the brown trout that are stocked there. An angler survey was conducted in 1987 in the Kingston basin (Mathers 1988), but the brown trout fishery has increased greatly (Dave Montgomery, pers. comm.). Therefore the 1987 survey would not likely reflect current brown trout harvests. A complete picture of stocking assessment cannot be presented without this component, as well.

Implications of Assumptions and Missing Data Components

Assumptions regarding clipping errors and fin regeneration in combination with the selected components of the fishery analyzed here lead to serious underestimates of the importance of stocked fish to the total Lake Ontario fishery in Ontario. Consequently, natural reproduction of brown trout and coho may be overestimated. In earlier years, clipping errors and regeneration may have been as high as 20% for coho but these rates are certainly much lower now. The quality control is now much higher for fin clipping in Ontario.

Natural Reproduction

Coho Salmon and Rainbow Trout

Coho salmon and rainbow trout reproduce naturally in Lake Ontario tributaries and these wild fish contribute significantly to catches in Lake Ontario. Most of these tributaries are in Ontario. Most of the wild fish appear to be produced in streams that are not stocked (D. Bell and L. Halyk, pers. comm.). Because of habitat limitation in streams that are stocked (e.g. Credit River, Bronte Creek, Rouge River), stocked fish do not contribute significantly towards providing natural reproduction in these streams. Accordingly, stocking of these species is currently on a put-and-take basis in Lake Ontario. Nevertheless, past stocking has contributed to the establishment of natural reproducing salmonids in Lake Ontario tributaries. The streams that are stocked have relatively poor habitat, and so natural reproduction is low. Small wild runs in these streams combined with straying are likely sufficient to seed population expansion should stream habitat improvement occur.

The potential for habitat improvement exists for some of the stocked streams. For example, Bronte Creek currently suffers from excessive summer water temperatures. If water temperatures can be sufficiently lowered through dam alteration or removal, then it may have the potential to produce a large number of salmonids (L. Halyk, pers. comm.). Stocking should then be lowered according to increases in natural reproduction, to maintain the current steady state between predator and prey fish in Lake Ontario

Brown Trout

In the following section, the thesis that "the Ganaraska strain of brown trout does not have smolting tendencies" will be developed. From this thesis it follows that this strain will be useful only for put-and-take fisheries in Lake Ontario rather than for rehabilitation in establishing wild runs of brown trout. It also follows that this strain may be suitable for inland stocking for either rehabilitation or put-and-take stocking

Stocked brown trout have colonized Limestone Creek, a tributary of Bronte Creek. In 1982, no brown trout were observed in Limestone Creek (Bowlby and Roff 1986). However, in 1987 after several years of stocking the mouth of Bronte Creek, Limestone Creek had the following num-

bers of young-of-the-year salmonids in a 30 m section (L. Halyk, pers. comm.): brown trout - 23, brook trout - 7, rainbow trout - 30, and coho salmon - 13. Apparently, brown trout are able to reproduce with comparable numbers to coho salmon and rainbow trout in this stream.

In addition, there were five 2 and 3 yr-old brown trout in this section, which suggests that they do not migrate downstream. This is consistent with our low estimates of natural reproduction among the fish caught in Lake Ontario. Also, in a downstream weir in Wilmot Creek in 1989, less than 100 brown trout were caught compared with thousands of rainbow trout and coho salmon smolts (M. Jones, pers. comm.), despite good populations of brown trout in the creek. Moreover, the brown trout caught in the weir were not silvered (L. Stanfield, pers. comm.), indicating they were not smolting.

Wilmot Creek is not stocked but other stream mouths nearby are stocked. This stocking practice encourages greater straying than upstream stocking, and thus Wilmot likely receives significant numbers of strayed brown trout at spawning.

Further evidence that this strain does not tend to migrate downstream comes from stocking of this strain into the Grand River in 1989 and 1990. From spring to fall 1989 the density of stocked brown trout in stocked areas of the Grand River dropped by 50% (L. Halyk, pers. comm.). Moreover, angling effort was observed to be intense suggesting that much of this drop was likely due to angling mortality (L. Halyk, pers. comm.).

Phil Smith and Dave Bell (pers. comm.), who were involved in the collection of the original brood stock from the Ganaraska River and Bowmanville Creek, have suggested that these fish were likely a mixture of New York hatchery strain and wild stream strains (stream fish which had by chance dropped downstream into the lake). The evidence presented here supports these suggestions.

In summary, the strain of brown trout stocked by Ontario appears to reproduce naturally but does not tend to smolt downstream like salmon or most strains of rainbow trout in Ontario. Further examination of this thesis and its implications to brown trout management practices in Ontario should be made.

An additional management consideration about this species is the likelihood that brown trout stocked into Lake Ontario may be responsible for the maintenance of brown trout populations in Lake Ontario tributaries. In the face of competition from rainbow trout, coho salmon, and chinook salmon which also spawn successfully in many of these streams, fishable stream brown trout populations exist in many Lindsay District streams (D. Bell, pers. comm.). Without the competitive numerical advantage from the stocked brown trout offspring, the brown trout population in these streams would certainly be lower, but how much lower we cannot say.

For streams where habitat does not afford year-round survival, protection of spawning brown trout should not be a priority. In such streams, extended seasons could be considered to increase angling opportunities and the harvest of stocked brown trout.

Fall Fingerlings vs Spring Yearlings

Coho fall fingerlings performed as well as spring yearlings, but are cheaper to produce. Moreover, stocking fall fingerlings has the potential to improve hatchery production by freeing up rearing space. Plante and Bowlby (1990) suggested "hedging bets" by continuing to stock in spring and fall. However, because of the additional data presented here, my position has changed. Now I recommend stocking fall fingerlings, where habitat is suitable, rather than spring yearlings. Because stocking occurs in several locations, there is still a considerable margin of safety from environmental catastrophes such as flooding. Fall fingerlings should be stocked only into habitats that are underutilized by wild salmonids, and then only up to the carrying capacity of the receiving streams. Models that assist in the determination of salmonid carrying capacity in Ontario streams are currently under development (e.g. Bowlby and Imhof 1989). If stocking above the carrying capacity is necessary then stock extremely fat yearlings during spring when the fish are ready to smolt. Fall fingerlings should be dispersed over a wider area than spring yearlings which are expected to smolt.

The use of fall fingerling stocking should not be restricted to coho salmon. Rainbow trout and brown trout have similar habitat requirements and behaviour to coho salmon, and should be considered for fall fingerling stocking under the same conditions as discussed above for coho. Experimental stocking of fall fingerling brown trout and rainbow trout should be evaluated against stocking of spring yearlings.

Acknowledgments

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OMNR's Zebra Mussel Monitoring Program on Lake Ontario, 1990.

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Lake Ontario Fisheries Unit 1990 Annual Report, LOA 91.1 (Chapter 5)

The progress of zebra mussel invasion in Lake Ontario in 1990 was monitored by OMNR in surveys using divers, artificial substrate samplers, and plankton samples. Zebra mussels were detected at several times and locations in the western basin, and in two instances in the Kingston basin and the Bay of Quinte. Findings by other agencies on the Canadian side confirm the pattern, and U.S. data indicate spreading along the south shore of the lake.

Recommendations

1. Continue monitoring zebra mussel through plankton and artificial substrate surveys. Artificial substrates could be installed later in the season than in 1990, and inspected only once at the end of the season.
2. Devise a method to measure cumulative settling rates, densities and size/age structure of zebra mussel, in order to secure data needed to interpret changes that will undoubtedly occur in the fish community.
3. Coordinate sampling methods with U. S. agencies to insure that the data are compatible.

Introduction

The year 1990 marked the beginning of zebra mussel (*Dreissena polymorpha*) invasion of Lake Ontario. The mollusk was probably introduced in North America in Lake St. Clair in 1986. It was first sighted there in June 1988, and in Lake Erie in July 1988. One year later Lake Erie had extensive zebra mussel colonies in its western basin. The first sighting in Lake Ontario was reported from Port Weller in November 1989, and in 1990 sightings from many areas around the lake became routine.

The program described in this report is the most extensive effort on the Canadian side of Lake Ontario. Several government agencies, universities, as well as private industry participate in zebra mussel monitoring, and their objectives range from prevention of economic injury to studies of the mussel's impact on the lake ecosystem. The OMNR program was designed to document the progress of the invasion, and to provide timely information to the public during the invasion's sensitive initial period.

Program Overview

The program consisted of three projects. A **diving survey** was carried out in the late spring. Subsequently, two concurrent surveys were started in June, and continued at monthly intervals until October: in the **artificial substrate survey** we installed and inspected Plexiglas settling plates for presence of settled mussels, and in the **veliger survey** we examined plankton samples for presence of zebra mussel veliger larvae.

Methods

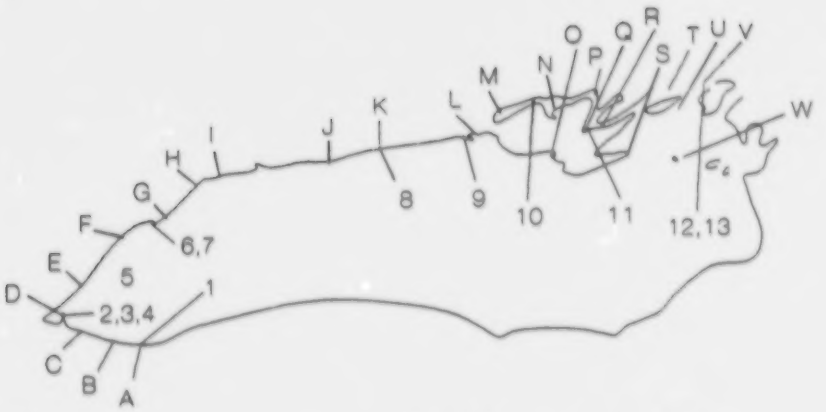
Diving Survey

The survey was completed in 2 weeks between May 30 and June 14, 1990. The 13 sites (Fig. 1) were not chosen randomly, but rather we sought to inspect locations that were likely to be already infested. Dives were made at Niagara-on-the-Lake and Port Weller, where Lake Erie water flows into Lake Ontario, and at docks throughout Lake Ontario where large boats possibly coming from Lake Erie tie up. At each location we examined as much of the underwater structures (walls, dolphins etc.) as possible during a one hour dive.

Artificial Substrate Survey

This survey was carried out at 23 sites between Niagara and Kingston (Fig. 1). Sampling devices were installed in June and inspected at monthly intervals between July and October. At five sites we deployed an array of nine samplers in three rows of three samplers running perpendicular to the shore. The distance between the rows was 500 m, and in each row the samplers were placed roughly at 3, 5 and 8 m depths. At the remaining sites we placed single samplers at the 5 m depth. A number of samplers were lost throughout the season and not replaced.

The samplers (Fig. 2) were made up of 152 x 152 mm (6 x 6 in) plates of 6 mm (1/4 in) sandblasted Plexiglas. A series of five plates were strung together with removable chain links (quick-links), and hung from an anchored buoy. During the first inspection in July the bottom plate was removed and replaced with a clean plate, and during subsequent monthly visits the two bottom plates were removed, and replaced with a single clean plate. The monthly samples therefore consisted of plates that were in the water since the beginning of the survey in June, as well as plates that were in the water for one month since the last visit. The plates were examined in the lab, noting the numbers and sizes of settled zebra mussels.



Diving survey:

1. Niagara-on-the-Lake
2. Hamilton Harbour
3. Burlington Bridge Canal
4. Burlington - CCIW
5. St. Lawrence Cement in Clarkson
6. Toronto Harbour
7. Toronto Harbour
8. Cobourg Harbour
9. St. Lawrence Cement in Colborne
10. Meyer's Pier in Belleville
11. Lake Ontario Cement in Picton
12. Kingston - Portsmouth Harbor
13. Kingston - Confederation Basin

Veliger and artificial substrate surveys (same locations for both surveys):

A. Niagara-on-the-Lake
B. Port Weller
C. Grimsby
D. Hamilton
E. Bronte
F. Port Credit
G. Scarborough
H. Whitby
I. Oshawa
J. Port Hope
K. Cobourg
L. Presqu'ile
M. Trenton
N. Big Bay
O. Wellington
P. Deseronto
Q. Picton
R. Glenora
S. Long Point
T. Amherst
U. Amherst Island
V. Kingston
W. Main Duck Island

FIG. 1. Locations surveyed in the 1990 OMNR zebra mussel monitoring program in Lake Ontario.

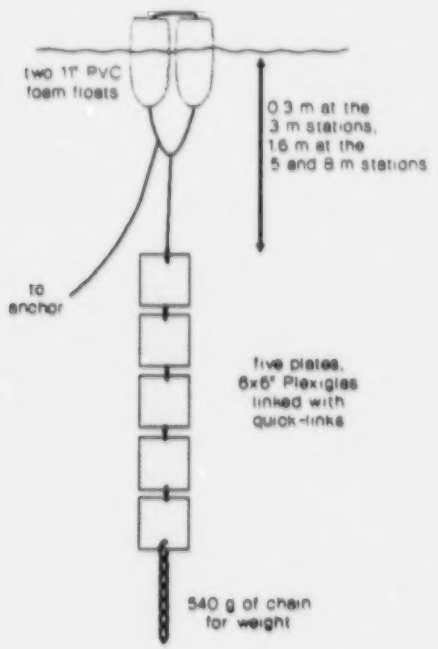

two 11" PVC foam floats
0.3 m at the 3 m stations, 1.6 m at the 5 and 8 m stations
to anchor
five plates, 6x6" Plexiglas linked with quick-links
540 g of chain for weight

FIG. 2. Artificial substrate sampler.

Veliger Survey

The veliger survey ran concurrently with the artificial substrate survey at the same times and locations, though samples were also obtained in June while installing the artificial substrate samplers. For most samples we pumped 1120 L of water from 2 m below the surface at a depth of 5 m. The water was pumped through a plankton net (initially 80 micrometres and later 53 micrometres), and the samples were preserved with buffered formalin.

The samples were concentrated down to 80 mL, and six 10 mL subsamples were examined, in most cases representing 840 L of lake water. Rather than examining the samples directly, the subsamples were settled through sugar syrup to speed up the examination. This method is estimated to recover 60% of the veligers present in the sample (Schaner 1990). The veligers were counted and measured along a line perpendicular to the axis bisecting the hinge.

Results

Diving Survey

Attached zebra mussels were detected at Niagara-on-the-Lake, at both Burlington sites, at Clarkson, and in Picton (Table 1). The densities were low; the highest density was found in Clarkson where 8 mussels were detected during the one hour dive. The sizes ranged from 8 to 18 mm.

TABLE 1. Numbers and sizes of attached zebra mussels detected in the diving survey, May 30 - June 14, 1990. Only sites where mussels were found are listed.

Site	Number found	Sizes (mm)
Niagara-on-the-Lake	5	9-18
Burlington Bridge Canal	1	8
Burlington CCIW	5	10-14
Clarkson	8	10-13
Picton	2	< 10

Settling Plate Survey

Attached mussels on artificial substrate samplers were found only in the southwestern corner of the lake, at the four sampling stations between Niagara and Hamilton (Table 2). There was a strong seasonal pattern in densities, with no settled mussels detected in July, followed by a peak in August, and a decline in September and October. The pattern was seen not only in plates that were replaced each month, but also in the 'cumulative' plates that were left in the water since June, though the latter generally had higher densities at any given time. The sizes of settled mussels varied between 0.4 and 9.4 mm. Small mussels (less than 2 mm) were found in August, and the range increased in September and October.

Only one station with an array of multiple samplers (Niagara-on-the-Lake) was located in the productive southwestern area. At this station it appeared that the samplers situated in deeper water collected more mussels than the ones from shallow water.

The ropes that anchored the samplers were also colonized by mussels. The extreme example occurred at Grimsby where the density of mussels attached to the rope was approximately 15,000/m^2, far exceeding the densities found on the sampler's Plexiglas plates (11/m^2). This probably represents the highest observed density in Lake Ontario in 1990.

Veliger Survey

Veligers were found along the shoreline between Niagara and Port Credit, and there was also an isolated

TABLE 2. Densities and sizes of attached zebra mussels detected in the artificial substrate survey. Only sites and months when mussels were found are listed. Estimates are based on observations from two sides of a single 152 x 152 mm (6 x 6 in) plate, in August and September, and two plates in October, except Niagara, where densities are based on four to nine plates, depending on the month.

	Density in #/m^2 (size range in mm)		
Site	August	September	October
Densities on plates placed in the water one month prior to examination:			
Niagara -on-the-Lake	476 (0.5-1.9)	9 (5.1)	4 (not avail.)
Port Weller	2002 (not avail.)	43 (0.6)	no sample
Grimsby	0	0	0
Hamilton	22 (0.4-0.9)	0	0
Densities on plates placed in the water in June:			
Niagara-on-the-Lake	2149 (0.6-2.3)	396 (2.2-9.4)	24 (0.6-8.2)
Port Weller	2562	108 (0.6-6.0)	no sample
Grimsby	0	0	11 (5.0)

finding at Main Duck Island in the eastern part of the lake (Table 3). The highest densities were encountered at Niagara-on-the-Lake and at Port Weller, and these two sites were also the only ones where veligers were seen in all months between June and September. Low numbers of veligers were found once during the summer at Hamilton, Bronte and Port Credit. No veligers were found anywhere on the lake in October. Sizes ranged between 80 and 220 micrometres, with a few individuals measuring up to 340 micrometres.

Discussion

Distribution of Zebra Mussels in 1990

The heaviest infestation of zebra mussel on the Canadian side of Lake Ontario remains for now confined to the western corner of the lake. Results described in this report indicate that the mussels have spread as far as Port Credit, though other monitoring programs[1] have detected attached mussels further east at Toronto (R. Dermott, Department of Fisheries and Oceans, pers. comm.) and Darlington (R. Claudi, Ontario Hydro, pers. comm.). Another cluster of sightings came from the eastern part of the lake: attached mussels in Picton (described in this report) and at Bath, and veligers in the water intake of the Celanese plant in Millhaven (D. McRobie, Celanese, pers. comm.). Along the U.S. shoreline, veligers and settled mussels have been found along the shoreline from the Niagara River to Oswego, and also in the Erie Barge Canal system (Kraft 1990) which is connected to Lake Ontario through the Oswego River.

Veliger densities detected in parts of Lake Ontario in 1990 may be close to those reported from Lake Erie in 1988. The densities found by OMNR are below the Lake Erie 1988 maximum of 20,000 veligers/m^3 (J. Leach, Ministry of Natural Resources, pers. comm.), but a comparable figure of 16,558 veligers per cubic yard has been reported from Somerset, N.Y., 30 miles east of the mouth of the Niagara River (R. Tuttle, New York State Gas and Electric, pers. comm.). High densities of attached mussels are also beginning to appear, for example 2571/m^2 detected on buoys at Port Weller (R. Dermott, Department of Fisheries and Oceans, pers. comm.), and 15,000/m^2 found on the ropes of samplers deployed by OMNR. Further spread is likely to be swift, be it due to distribution of Lake Erie veligers by lake-wide currents driven by the Niagara River, or to spread from isolated colonies that are establishing themselves around the lake.

Evaluation of the OMNR Monitoring Program.

Several lessons were learned in the 1990 program which was conceived in a hurry, and without experience in zebra mussel sampling techniques.

The artificial substrate samplers detected settled mussels, but probably did not reflect cumulative settling rates. The densities found in September and October were significantly lower than the peak densities found on the same samplers in August, indicating that mussels were falling off or detaching themselves. The samplers still have the advantage of integrating the settling rates over a period of time, but, since detachment occurs, they do not reflect the cumulative rates over the entire season.

The samplers at some locations became heavily fouled by *Cladophora*, so that counting was time-consuming, and probably unreliable with respect to small individuals. It also appears that the the sandblasted Plexiglas surface may be less than ideal for zebra mussel colonization, since the ropes were more heavily covered than the sampling surfaces.

Plankton sampling for veliger larvae proved to be at least as effective as the artificial substrate sampling, and easier to carry out. Samples for analysis were available (and tested positive) right from the beginning of the sampling season. With the low densities of veligers found in 1990 it proved crucial to examine large volumes of water, and it will probably remain necessary to do so in Lake Ontario for at least one more year.

Acknowledgements

I would like to thank all participants in zebra mussel monitoring programs on Lakes Erie and Ontario for freely sharing their data and experiences. Joe Leach was espe-

TABLE 3. Densities and sizes of attached veliger larvae detected in plankton samples. Only sites and months when mussels were found are listed. Most samples were based on 840 L of lake water, and the densities were corrected for an assumed 60% detection efficiency.

	Density in #/m^3 (sizes in micrometres)			
Site	June	July	August	September
Niagara-on-the-Lake	40 (111-225)	671 (88-339)	8 (121-146)	32 (95-244)
Port Weller	4 (142-157)	200 (99-227)	28 (85-195)	16 (81-243)
Hamilton	0	0	8 (170-195)	0
Bronte	0	16 (138-203)	no sample	0
Port Credit	0	8 (170-228)	0	0
Main Duck Island	no sample	8 (232-268)	no sample	no sample

1 *Summary of 1990 sightings on Lake Ontario is in preparation by OMNR, Glenora and NYDEC, Cape Vincent, for publication in March 1990.*

cially helpful. The Operations and Systems staff at Lake Ontario Fisheries Unit made the program run without a hitch, Alastair Mathers and Tom Stewart commented on a previous draft, and Linda Balsillie and Carol Ward gave it the look of a real report.

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Detection of Zebra Mussel Veligers In Plankton Samples Using Sugar Solution.

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Lake Ontario Fisheries Unit 1990 Annual Report, LOA 91.1 (Chapter 6)

A method is presented to efficiently detect presence of zebra mussel veligers in plankton samples. The veligers can be separated from many other constituents of the sample by allowing the sample to settle through a column of sugar solution. Most of the veligers are recovered within 20 min in a few drops of liquid at the bottom of the column, allowing quick examination. The method is especially suitable for initial detection of veligers at low concentrations, but potentially it also has quantitative applications.

Introduction

In 1990, the Ontario Ministry of Natural Resources started to monitor zebra mussel (*Dreissena polymorpha*) in Lake Ontario. Since the mussel was just beginning to invade the lake, and population densities were expected to be low, we examined large volumes of water to reliably detect presence of the mussel's veliger larvae. The method described here was developed to speed up processing of the samples, and to reduce analytical costs.

Materials and methods

Plankton samples were processed through a settling apparatus consisting of a 25 ml pipette fitted with a three-way rubber pipetting bulb (Fig. 1). The pipette was partly filled with sugar solution (Table 1), and the plankton sample was introduced over the top of the solution. Planktonic organisms were allowed to settle through the sugar solution for a period of time, and were then collected from the tip of the pipette.

The pipette was FISHERbrand 25 ml in 1/10 (#13-665 SZ N). The outflow tip of the pipette was sanded off to the point where the inner diameter was approximately 1.5 mm. This prevented clogging of the opening with large organisms and filamentous algae. The pipette was filled with sugar solution up to the "10 ml" mark (slightly more than 15 ml of liquid or a column 195 mm tall). A 10 ml plankton sample topped up the liquid to the "0 ml" mark.

To set up the settling apparatus, the sugar solution was first drawn into the pipette using the rubber bulb. The tip was then sealed off with Parafilm, and the bulb removed. The plankton sample was introduced from the top using a syringe, and the timer was started . In a quick succession, the bulb was fitted back on the pipette, the Parafilm was removed, and any hanging drops were wiped off. Samples were periodically withdrawn from the tip of the pipette by pressing the "E" button (Fig.1) of the rubber bulb gently and slowly so that a single drop of liquid was released onto a depression slide.

Rates at which veligers settle through the apparatus were investigated by processing plankton samples, either containing known numbers of veligers, or representing batches of known veliger concentration. In all cases the samples were preserved with buffered formalin (Table 1) for at least 0.5 h before processing to allow osmotic equalization. Drops with settled organisms were collected from the tip of the pipette at 2 or 5 min intervals over a period of up to 30 min, and examined under a dissecting microscope at 25x magnification. To indicate efficiency, the numbers of recovered veligers were expressed as percentage of the number introduced into the apparatus.

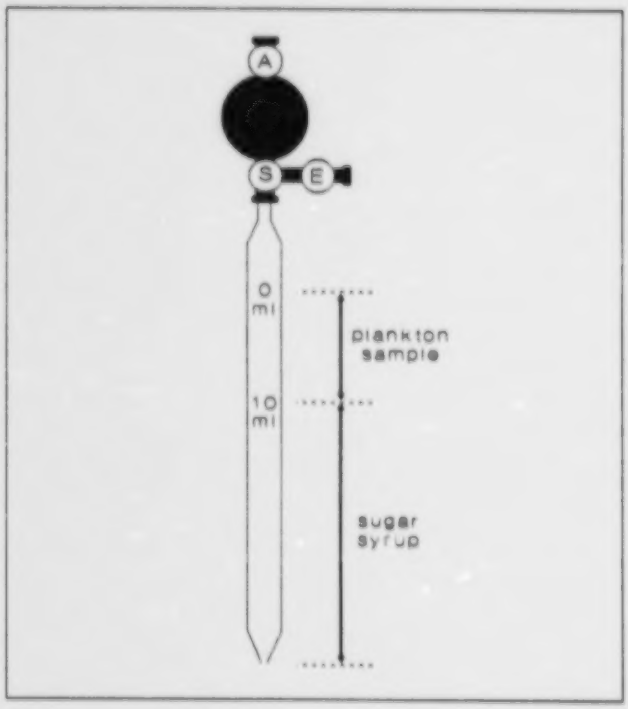

FIG. 1. The settling apparatus.

TABLE 1. Composition of preservative fluid and sugar solution used in processing of the plankton samples.

Preservative fluid:

(Modified after G.Hopkins
Ontario Ministry of Environment
Rexdale, pers. comm.)

37% formaldehyde	850 ml
Distilled water	1000 ml
Sugar	500 g
Sodium bicarbonate to raise pH to 7.0	

Combining 1 part of this solution with 4 parts of plankton sample results in approximately 4% formaldehyde concentration.

Sugar solution:

Sugar	130 g
Distilled water	400 ml

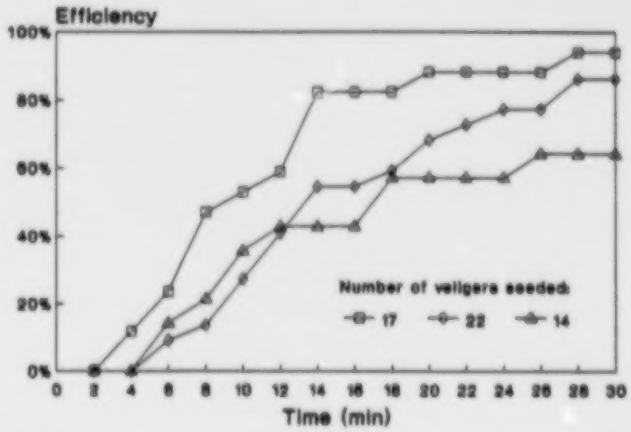

FIG. 2. Settling rates measured by allowing exactly known numbers of veligers to settle through the sugar column in almost complete absence of other organisms. Counts were made at 2 min intervals, and are expressed as cumulative (over time) percentages of the starting numbers.

Results

Veligers

The ideal settling rates and efficiencies for veligers were examined in three trials in which known exact numbers of veligers were introduced into the apparatus. Few other particles and organisms were present to interfere with veliger settling. The first veligers settled at 2 to 4 min (Fig. 2), and settling began to level off at 15 to 20 min. After 30 min the cumulative number of settled veligers represented 75-94% of the numbers used to seed the samples.

Tests with "real" plankton samples showed similar or somewhat lower efficiencies. After 20 min of settling, mean efficiencies ranged between 55 and 85%, and increased up to 90% at 30 min (Fig. 3A, B, C). The efficiencies appear to vary depending on the overall particle concentration of the introduced plankton sample. A very dense plankton sample from Nanticoke, Lake Erie, was diluted to 20 and 50% of original concentration, and a series of tests were run with each of the two batches. The more diluted batch (20%, Fig. 3B) showed efficiencies similar to ones experienced with veliger-only samples (Fig. 2), while the efficiencies with the more concentrated batch (50%, Fig. 3C) were lower, and arrivals at the bottom of the pipette leveled off only slightly during the 30 min experiments. This suggests that in highly concentrated samples the veligers are prevented from settling through the introduced sample to the top of the sugar column.

Size selectivity of the settling process was investigated using measured veligers mixed with a veliger-free plankton sample to simulate a realistic sample. Sizes of settled veligers were compared with those in the original sample. It appears that the size composition of the veligers settling through the apparatus within 25 min tended to be biased towards larger individuals (Fig. 4), though the difference from the original size frequency distribution was not statistically significant (chi-square and Kolmogorov-Smirnov tests, $p > 0.1$).

Other Organisms and Debris

The settling times for the other plankters varied. Too few experiments were performed to confidently describe the generalities. However, two observations appear reliable: 1) inorganic debris tended to settle within the first 4 min, and 2) cladocerans started arriving after approximately 15 min. At 30 min the arrivals of all types of particles began to decrease, though the liquid above the sugar column remained turbid.

Discussion

Settling the plankton samples through a column of sugar solution can be useful in detection of zebra mussel veligers. A high proportion of the veligers passed through the settling apparatus within the time window of 5 to 20 min, and allowed separation from both early-settling inorganic debris, and late-settling planktonic organisms. The bias in sizes of the settled veligers was small.

The method offers several advantages. Firstly, a bank of settling pipettes can be set up and operated simultaneously, and thus samples representing large volumes of water can be rapidly processed. In our sampling program, two people were able to process and microscopically examine samples representing 840 litres in 40 min. Fatigue is minimized since very little time is spent in microscopic examination. Various types of organisms tend to settle at various times, and if samples of settlers are taken periodically throughout the settling period, then the lesser variety of organisms in any single sample leads to easier detection of veligers. Fractions of the plankton sample can be discarded with little decrease in efficiency: discarding a drop at 3 min and then stopping the process at 20 min, will avoid sand and silt particles as well as most cladocerans, while still capturing at least half of the veliger larvae.

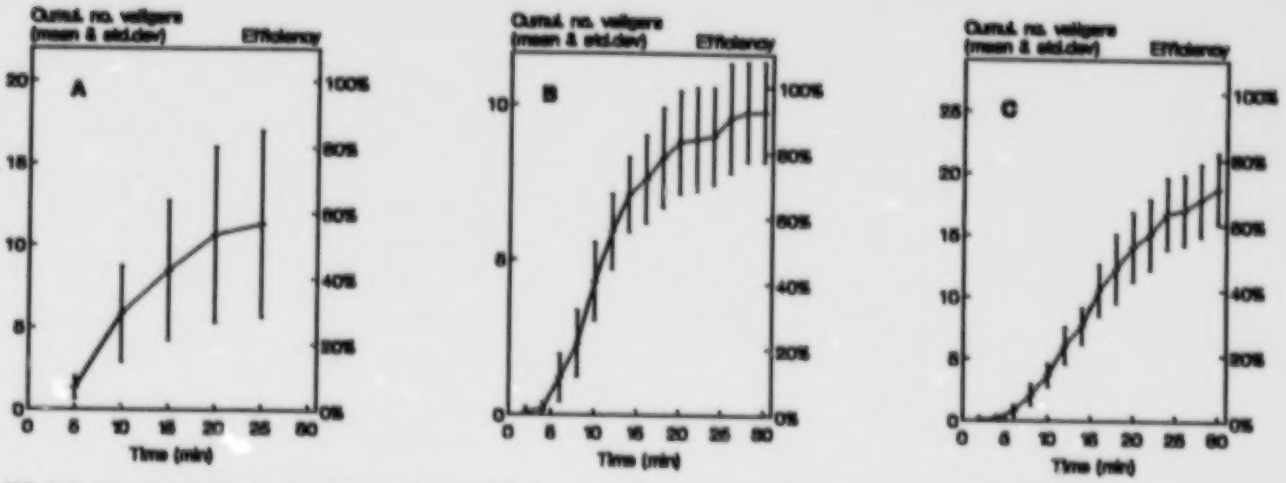

FIG. 3. Settling rates of veligers, measured in samples that included other plankton organisms. Each graph represents several replicate runs, and the mean cumulative (over time) count is shown. The replicates were taken from known concentrations of veligers, but the exact number of veligers in each replicate was not known. Therefore, some part of the standard deviation is due to variability in the starting numbers. Efficiency is the number of recovered veligers expressed as percentage of the starting numbers. A: Lake Erie veligers mixed with veliger-free plankton sample from Lake Ontario, six replicate trials. B: Plankton sample with veligers from Nanticoke, Lake Erie diluted to 20% original strength, nine replicate trials. C: Same as B, but diluted to 50%, eight replicate trials.

It appears that efficiency decreases when the plankton sample is too concentrated and veligers are impeded in reaching the sample-sugar interface. The data presented here indicate approximate efficiencies, and allow for rough correction. No guidelines for maximum particle concentration are given here, though establishing such guidelines would render the method more suitable for quantitative applications.

The most logical application of this method is in the initial detection of zebra mussel infestation, when veliger densities are on the order of several veligers per cubic metre. Here the drawback of incomplete enumeration is offset by the ability to examine large volumes of water.

Acknowledgments

I thank Joe Leach, Dave Lowther, and Don Lewis for providing veliger larvae and plankton samples, and Gord Hopkins for providing the formalin recipe.

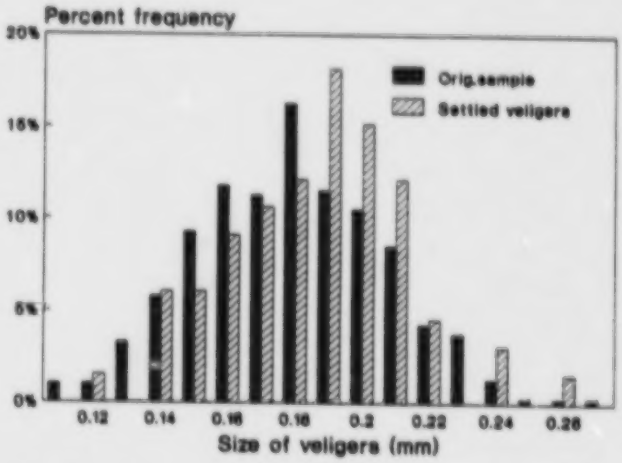

FIG. 4. Size selectivity of the settling process: size frequency distribution of introduced sample (400 veligers measured, sample from Fig. 3A) contrasted with distribution of veligers settled within 25 min (66 veligers pooled from six replicate runs).

Gillnet Survey in the Western Basin of Lake Ontario

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Lake Ontario Fisheries Unit, 1990 Annual Report LOA 91.1 (Chapter 7)

Gillnet data from three depth stratified transects sampled throughout the year during 1972-73, and similar data collected during July, 1977 to 1986, in conjunction with gillnet data from four areas at two depths during June and July 1990, were examined to re-evaluate bottom gillnets for fish community indices in western Lake Ontario. Alewife dominated the catch in all years. During 1972 to 1986, smelt were the second most abundant species. Fewer smelt were caught in 1990, likely due to a change from multifilament to monofilament gillnets. Lake trout increased in the catch coincident with increased stocking from 1972 to 1990. However, there was no corresponding increase in the catch of other salmonines coincident with increased stocking. Few fish of other species were caught. The abundance of alewife, smelt, and lake trout was better indexed in other programs, and bottom gillnetting did not appear to provide a cost-effective index for the remaining species.

Recommendations

1. Bottom gillnetting during summer is not recommended for providing a long-term fish community index in western Lake Ontario.
2. Develop hydroacoustics and midwater trawling to sample salmonines in western Lake Ontario.
3. Expand the fall lake trout index gillnet program to include sampling in shallow water to obtain a low resolution index of abundance for suckers, coregonines (e.g. round whitefish), and other nearshore species.

Introduction

The provision and maintenance of long-term indices of fish populations in Lake Ontario is the highest Assessment Unit priority for the Lake Ontario Fisheries Unit (LOFU). Currently, LOFU index programs assess lake trout, alewife, and rainbow smelt in the Canadian waters of western Lake Ontario (i.e. west of Brighton). However, there are no LOFU index programs in these waters that assess the abundance of fish comprising the warmwater community or other large members of the coldwater community, such as coho salmon, chinook salmon, rainbow trout, and brown trout.

The Glenora Research Station (GLR, now part of LOFU) conducted gillnetting in Lake Ontario in 1972-73 during spring, summer, fall, and winter at a range of depths. The same locations were sampled from 1977 to 1986, during July.

In 1990, LOFU gillnetted two depths near the Port Credit and Cobourg Research transects during June and July. These data and the historic research gillnet series were used to re-evaluate bottom gillnets for fish community indices in western Lake Ontario. Specifically, we were interested in designing a fish community index netting program that would include all of the salmonine species in the lake.

Methods

1972

Bottom gillnets were set near Port Credit, Cobourg, and Rocky Point (Fig. 1), during June, July, September, and October 1972, and February, March, and May 1973. Nets were set generally at depths of 9, 27, 46 or 55, 73, 110, and 146 m, but not all depths were fished in all months. A more complete depth/mo distribution of effort is found in the Results. Gillnets were the standard GLR lake multifilament design composed of panels of 38-152 mm (1.5-6.0 in) mesh in 12.7 mm (0.5 in) increments (Hurley 1987). A standard lift was calculated as the sum of the catch adjusted to 100 m effort for each panel.

1977-1986

Bottom gillnets were set at the same transects as in 1972 during July or occasionally the first week of August 1977-1986. Data for 1980 were not presented here due to technical difficulties, but the data patterns are not affected greatly by their absence. Nets were set generally at depths of 9, 27, 46 and 73 m, but not all depths were fished in all years. A more complete depth/mo distribution of effort is found in the Results. The net design was the same as 1972. A standard lift was calculated as above.

1990

Bottom gillnets were set at randomly selected transects in four areas near Hamilton, Burlington, Port Hope, and Cobourg (Fig. 1), during June and July 1990. Nets were set at depths of 7.5 and 22.5 m, parallel to shore. Nets were composed of 4.6 m (15 ft) of 38 mm (1.5 in) multifilament, 45.7 m (150 ft) each of 51 and 102 mm (2 and 4 in) multifilament, and 15.2 m (50 ft) of 64, 76, 89, 114,

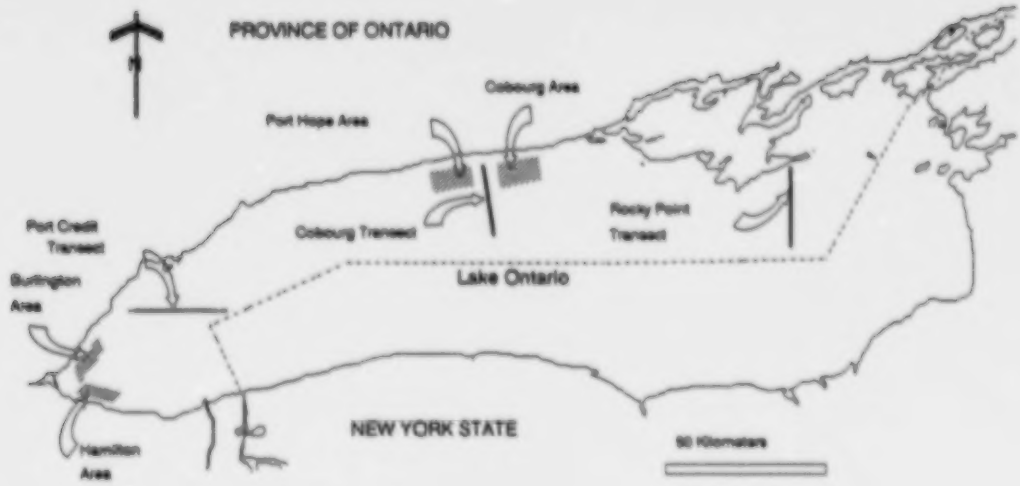

FIG. 1. Gillnetting transects and areas in Lake Ontario.

and 127 mm (2.5, 3.0, 3.5, 4.5, and 5.0 in) monofilament. A standard lift was calculated as above. Note that a standard lift in 1990 was not comparable to previous years.

Analysis of covariance (ANCOVA) was used to test for catch correlations between depth for each species after controlling for area and month effects. Then multivariate analysis of variance (MANOVA) was used to test for catch differences in areas and months across depths by species. The F-test for the MANOVA was based on Wilks' Lamda. Catch data were log transformed (log[100X + 1]) before analysis. The Hamilton area was excluded from this analysis because it was not sampled in June. The level of significance used here was $P = 0.05$.

Results

The reader should bear in mind that these results are presented and discussed in terms of future program design rather than the ecological aspects of the seasonal and yearly trends of the data. There are some interesting patterns in the data and LOFU Research has indicated a commitment to more detailed ecological analyses of these data (J. Casselman, pers. comm.). I hope the graphic data summaries presented here encourages such work.

1972

Smelt and alewife dominated the catches from all transects (Table 1). Relatively few other species were present in the catch and most of these were caught in less than 40 m. Yellow perch were abundant only at Rocky Point. Lake trout were absent and a small number of coho and chinook salmon were caught at Port Credit. Notably, most salmon were caught in September (Fig. 2) and this likely reflected the staging of fish before the spawning run up the Credit River.

Other seasonal peaks in catch also appear to correspond with spawning or pre-spawning aggregations for a number of species, such as alewife, smelt, white suckers (Fig. 2). For instance, alewife show a movement from deep water in spring to shallow water in June during spawning and then back to deep water in October. Smelt show a similar movement to shallow water but move to deeper water more readily than alewife. White suckers were always caught in less than 20 m and their catches peaked in June at the two sites closest to spawning rivers (Cobourg Creek and Credit River).

TABLE 1. Mean gillnet catch/standard lift of fish during 1972 for all depths and all months in Lake Ontario.

Species	Cobourg	Rocky Point	Port Credit
Alewife	386.4	308.8	301.0
Gizzard shad	0.0	0.1	0.0
Coho salmon	0.0	0.0	0.5
Chinook salmon	0.0	0.0	0.1
Lake whitefish	0.1	0.0	0.0
Lake herring	0.0	0.3	0.0
Round whitefish	0.8	0.0	0.0
Rainbow smelt	164.3	55.2	132.3
White sucker	7.9	0.2	5.9
Lake chub	1.6	5.6	7.2
American eel	0.0	0.3	0.0
White perch	0.4	0.6	0.1
White bass	0.1	0.0	0.3
Rock bass	0.2	1.2	0.2
Pumpkinseed	0.0	0.1	0.0
Smallmouth bass	0.0	0.9	0.1
Yellow perch	0.2	26.7	0.1
Freshwater drum	0.0	0.3	0.0
Sculpins	3.3	1.8	0.4

1977-1986

During these years, smelt and alewife were the most abundant species in the catch, as in 1972 (Table 2). In the Lake Ontario studies, it has been shown that gillnets tend to catch the larger individuals of these species (Casselman et al. 1990, Mathers and Stewart 1990, O'Gorman et al. 1990). For instance, the alewife collapse in 1977 and the decline of large smelt in more recent years that have

TABLE 2. Mean gillnet catch/standard lift of fish during July for all depths during 1972, 1977-79, and 1981-86 in Lake Ontario.

Species	Cobourg	Rocky Point	Port Credit
Sea lamprey	0.0	0.0	0.1
Alewife	2269.3	946.2	1607.4
Gizzard shad	0.1	0.5	0.0
Coho salmon	0.2	0.0	0.7
Chinook salmon	0.9	1.0	0.7
Rainbow trout	1.0	0.0	0.7
Brown trout	1.1	0.3	0.2
Lake trout	20.4	38.1	62.3
Lake whitefish	0.0	0.7	0.0
Lake herring	0.0	0.6	0.0
Round whitefish	0.8	0.0	0.0
Rainbow smelt	291.6	140.3	116.4
Longnose sucker	0.0	0.0	0.1
White sucker	7.0	0.6	12.3
Lake chub	0.1	6.1	1.8
Carp	0.0	0.0	0.1
Brown bullhead	0.1	0.0	0.0
Trout-perch	0.0	0.1	0.0
White perch	0.1	0.1	0.4
White bass	0.0	0.0	0.1
Rock bass	0.1	2.1	0.0
Smallmouth bass	0.0	2.1	0.0
Yellow perch	0.9	12.9	0.0
Walleye	0.0	0.2	0.0
Freshwater drum	0.1	0.0	0.0
Sculpins	3.4	0.8	0.2

been documented in these studies are also apparent in the data presented here (Fig. 3). Salmonines increased in the catch (Fig. 3), particularly in the early 1980's as stocking increased (LeTendre and Savoie 1990), but then generally decreased in the mid 1980s. Moreover, catches for all salmonine species except lake trout were inconsistent and low.

1990

The catch composition did not differ greatly from previous years described above (Table 3, Fig. 4). Alewife dominated the catches followed by lake trout, white suckers, round whitefish, and smelt (Table 3). These catches are not directly comparable with the results from previous years because of the difference in gear. For instance, smelt catches were much lower in 1990 than previous years because smelt appear to be caught by their teeth more readily in multifilament than in monofilament gillnets. Nevertheless, the qualitative comparisons suggest that the community vulnerable to this gear has not changed much from previous years.

There were few significant differences among areas, depths and months. These differences were summarized as follows. Lake trout catches were significantly greater in July than June (MANOVA, $F = 6.86$, $P = 0.006$). Round whitefish were caught in significantly greater numbers at Cobourg and Port Hope than at Burlington (MANOVA, $F = 66.93$, $P = 0.0001$). White suckers were caught in significantly greater numbers at Cobourg (MANOVA, $F = 3.32$, $P = 0.02$) and were caught in significantly greater numbers in shallow water (ANCOVA, $F = 6.59$, $P = 0.019$).

TABLE 3. Mean gillnet catch/standard lift of fish during June and July, 1990 for all depths in Lake Ontario. Note that these values are not directly comparable with those in Tables 1 and 2 because different gear was used.

Species	Burlington	Hamilton	Cobourg	Port Hope
Alewife	533.5	207.7	542.9	444.2
Chinook salmon	2.8	2.5	2.5	1.2
Rainbow trout	0.0	0.0	0.4	0.0
Atlantic salmon	0.0	0.0	0.4	0.0
Brown trout	1.4	2.5	3.3	0.8
Lake trout	38.5	109.1	98.1	94.7
Lake whitefish	0.0	0.0	0.4	0.0
Round whitefish	0.3	0.0	22.3	23.7
Rainbow smelt	12.8	0.0	10.2	11.1
White sucker	13.2	30.4	21.4	9.4
Redhorse sucker	0.0	0.8	0.0	0.0
American eel	0.3	0.0	0.0	0.0
White perch	0.7	4.1	4.5	0.8
Yellow perch	0.3	3.3	0.0	0.0

Discussion

Gillnetting in western Lake Ontario during summer did not complement our other index fishing programs. Alewife, smelt and lake trout were the most abundant species in the gillnet catches, but these species were already targeted in other programs. Alewife and smelt have been best indexed by ongoing midwater and bottom trawling programs (Mathers and Schneider 1991; Mathers and Stewart 1990), and these programs have provided a more representative length distribution than from gillnets. Lake trout have been indexed in the fall lake trout index gillnet program (Schneider et al. 1990). Other salmonids, particularly coho salmon, chinook salmon, rainbow trout, and brown trout were not caught in sufficient numbers for meaningful biological sampling, and trends have shown high variability in catches from year-to-year. Increased effort and wider distribution of gear would reduce variability in trends and increase the number of biological samples. However, this would increase the kill of lake trout to an unacceptably high number (i.e. far more than necessary for biological sampling). Other species such as white suckers and round whitefish were relatively few in number, and at these densities are relatively unimportant ecologically or economically, and alone could not justify an index program. In addition, warmwater species were extremely rare. Accordingly, bottom gillnetting during summer is not recommended for providing a long-term fish community index in western Lake Ontario.

The important missing component of the western Lake Ontario fish community continues to be the large salmonines, other than lake trout. These salmonines appear to be nomadic and unpredictable in location. Thus, the traditional approach of using index stations at a particular time tends to be a "hit or miss affair". However, ongoing

work with midwater trawling and hydroacoustics (Schaner 1991) suggests that a combination of these gears may be the best approach to indexing these species. This is because only hydroacoustics has the potential to cost-effectively sample large enough volumes of water to avoid the difficulties associated with salmonine distribution. Efforts to develop these gears should be continued.

A low resolution index of abundance for suckers, coregonines (e.g. round whitefish), and other nearshore species could be obtained through expanding the fall lake trout index gillnet program to include sampling in shallow water. The data presented above (Fig. 2, 3, 4) indicates that the depth zone less than 20 m contains most of the species that are not currently indexed in other programs.

Acknowledgments

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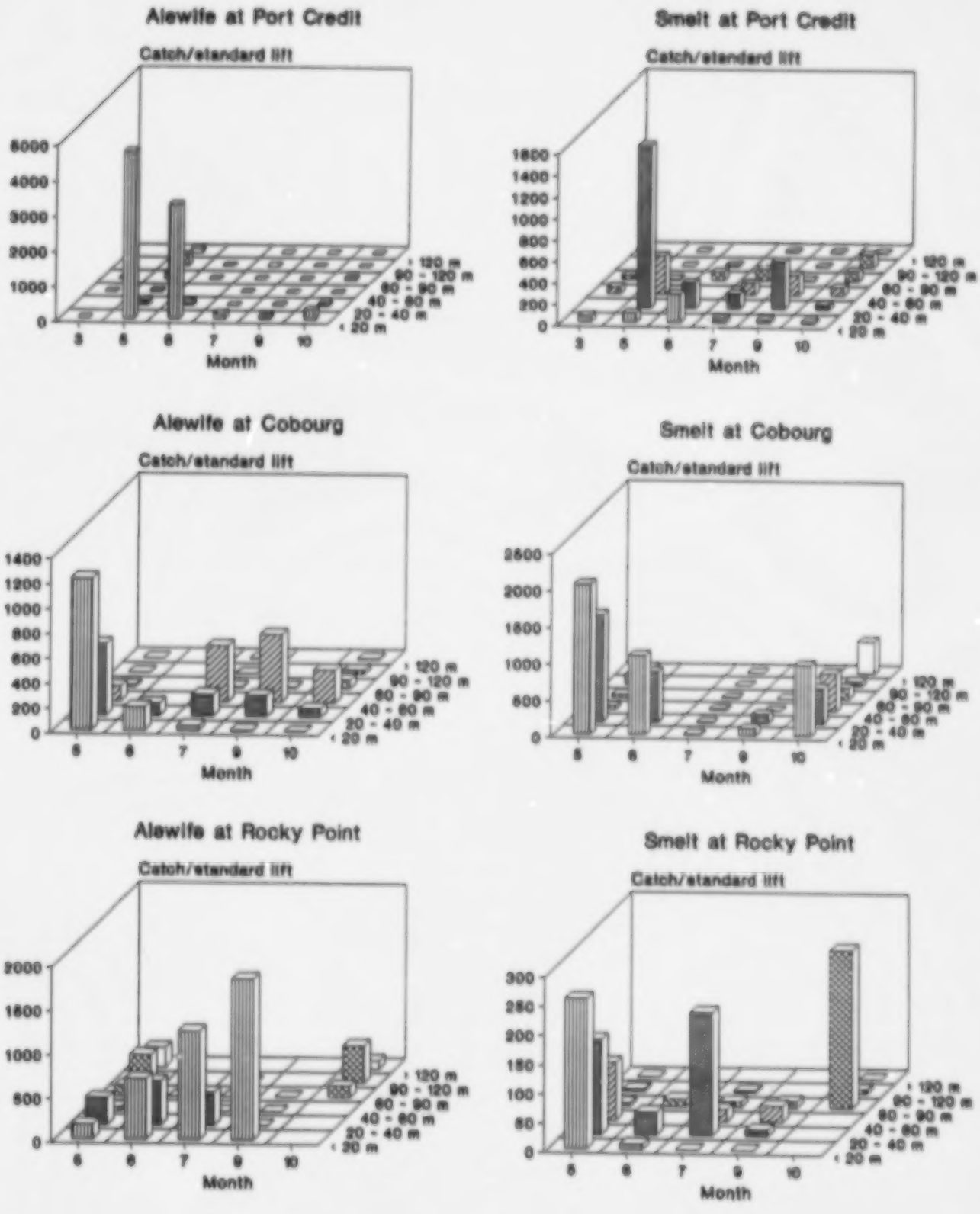
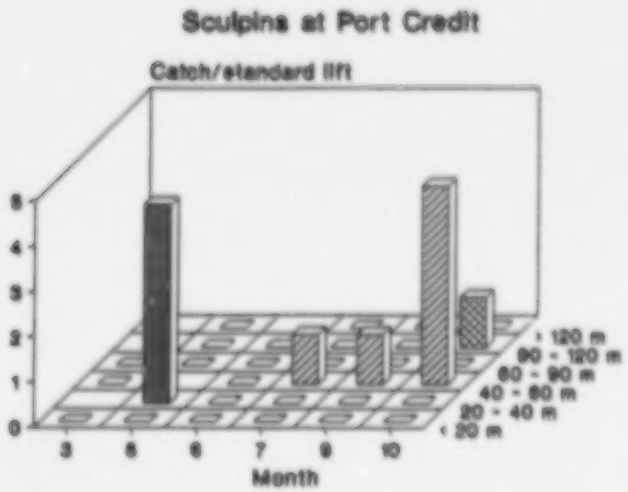
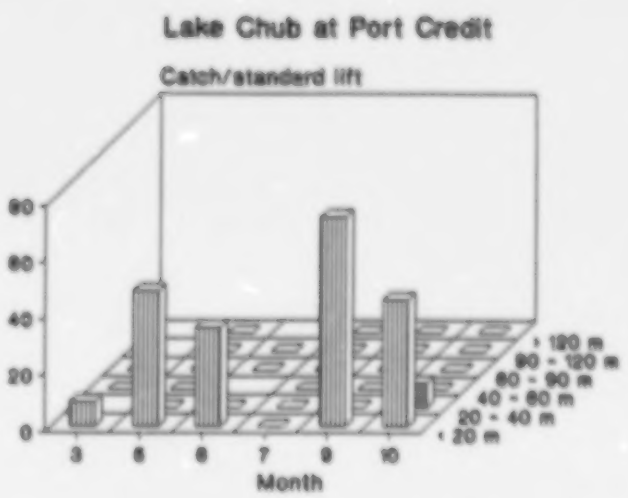
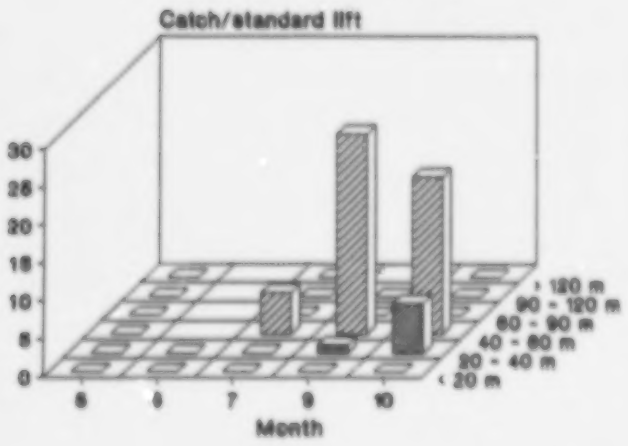
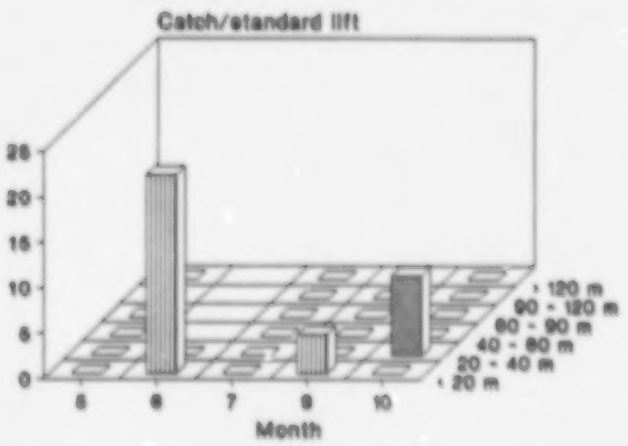


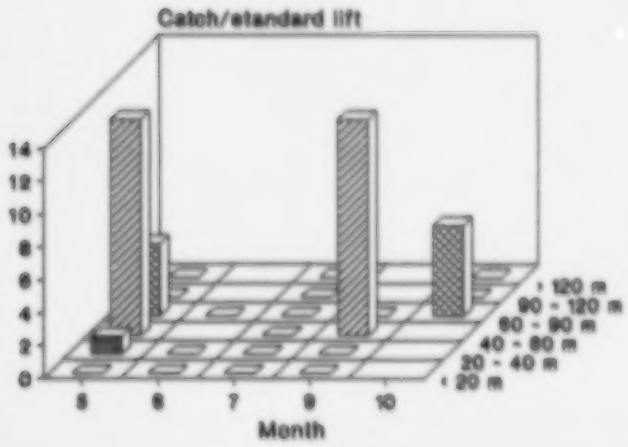
FIG. 2. Catch rates of index gillnets in Lake Ontario, June 1979 - May 1973, by depth.

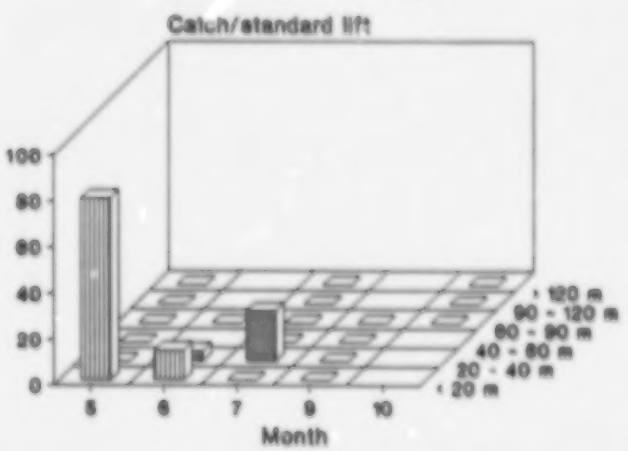












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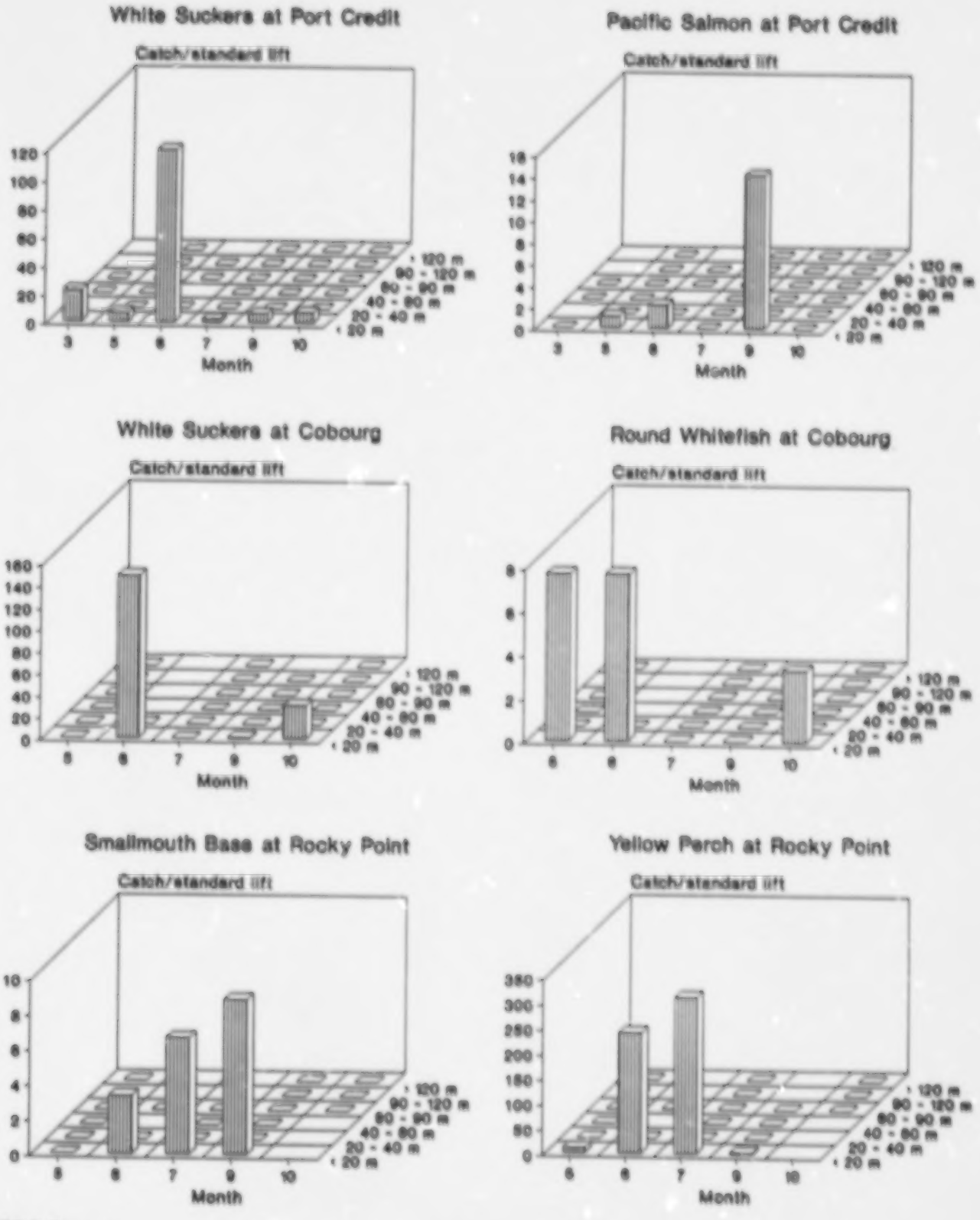

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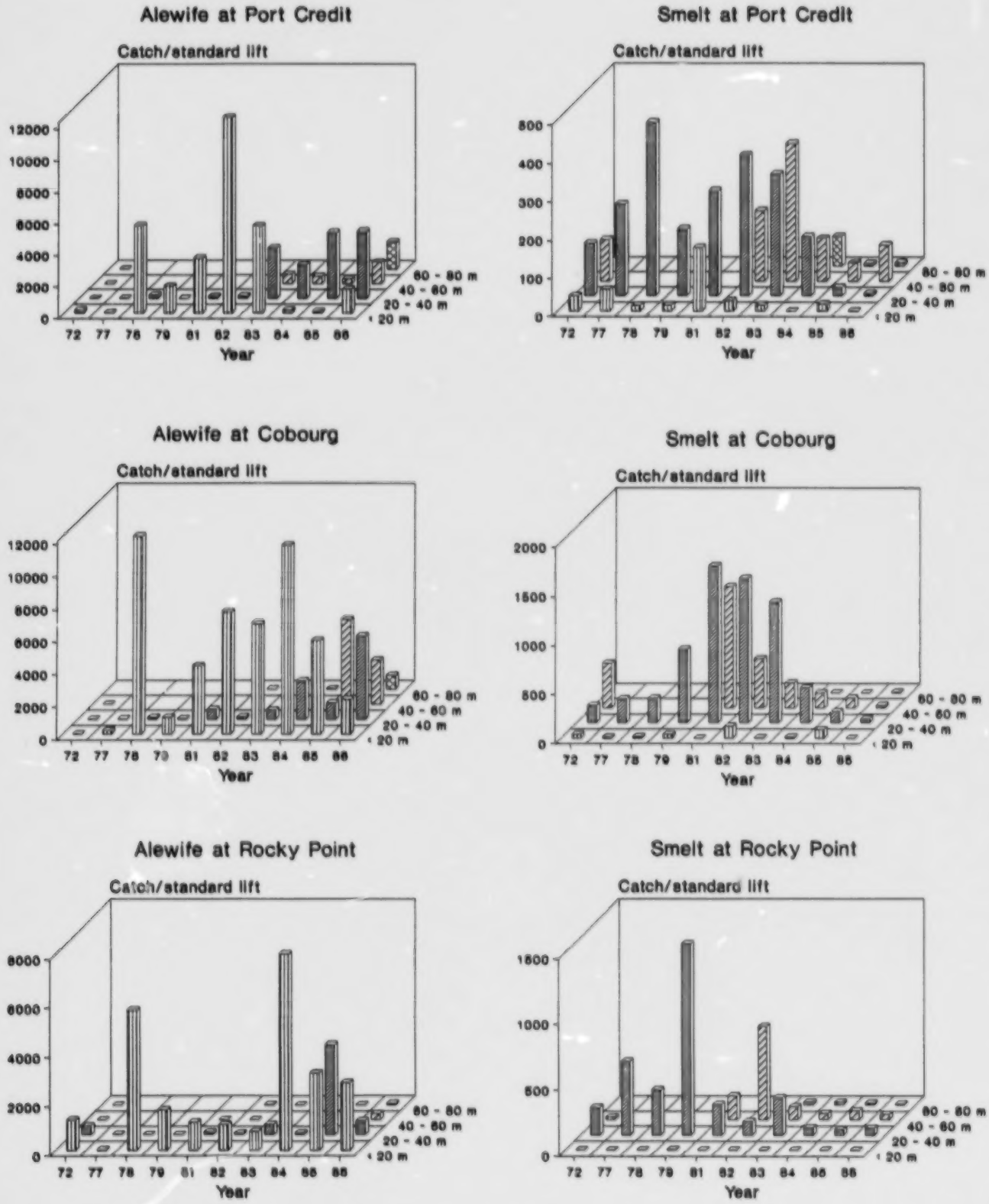
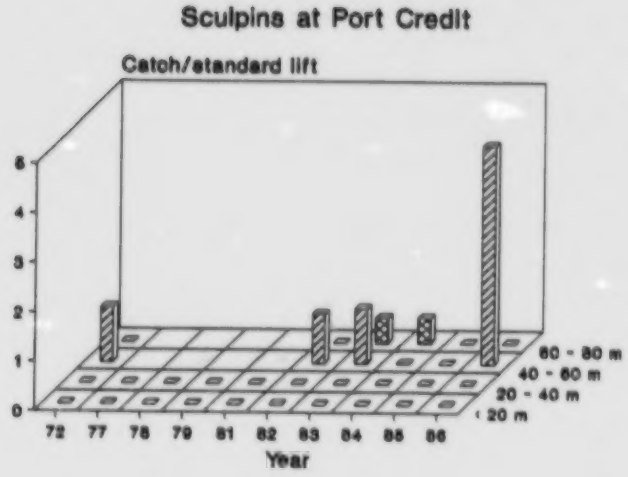
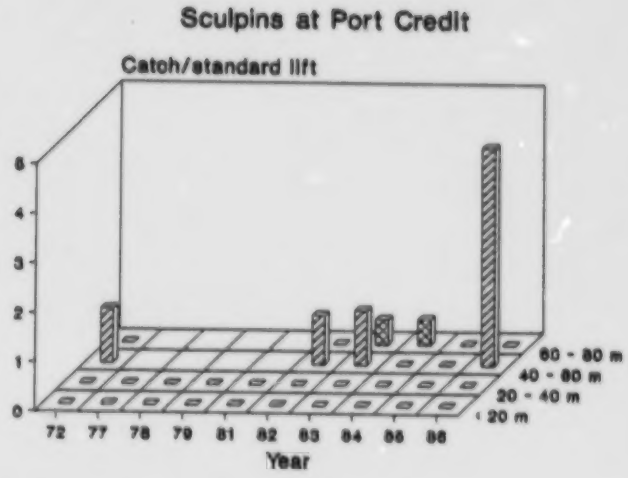
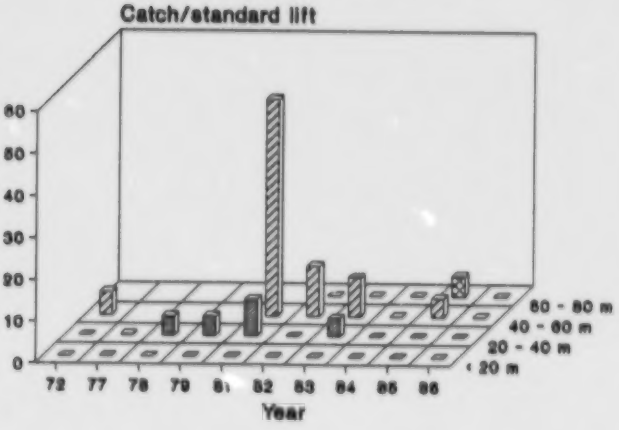
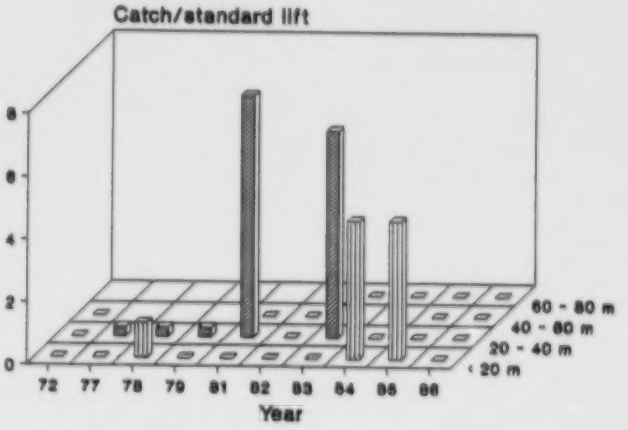


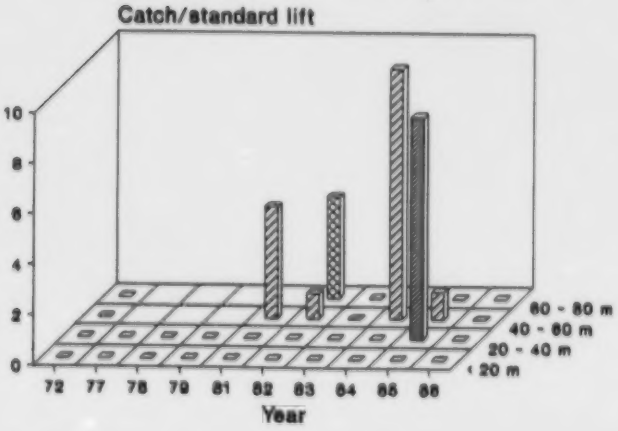
FIG. 3. Catch rates of index gillnets in Lake Ontario during July for 1972, 1977-1979, and 1981-1986 by depth.

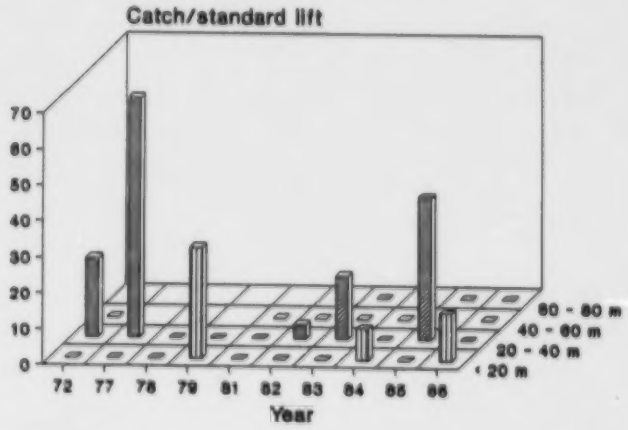












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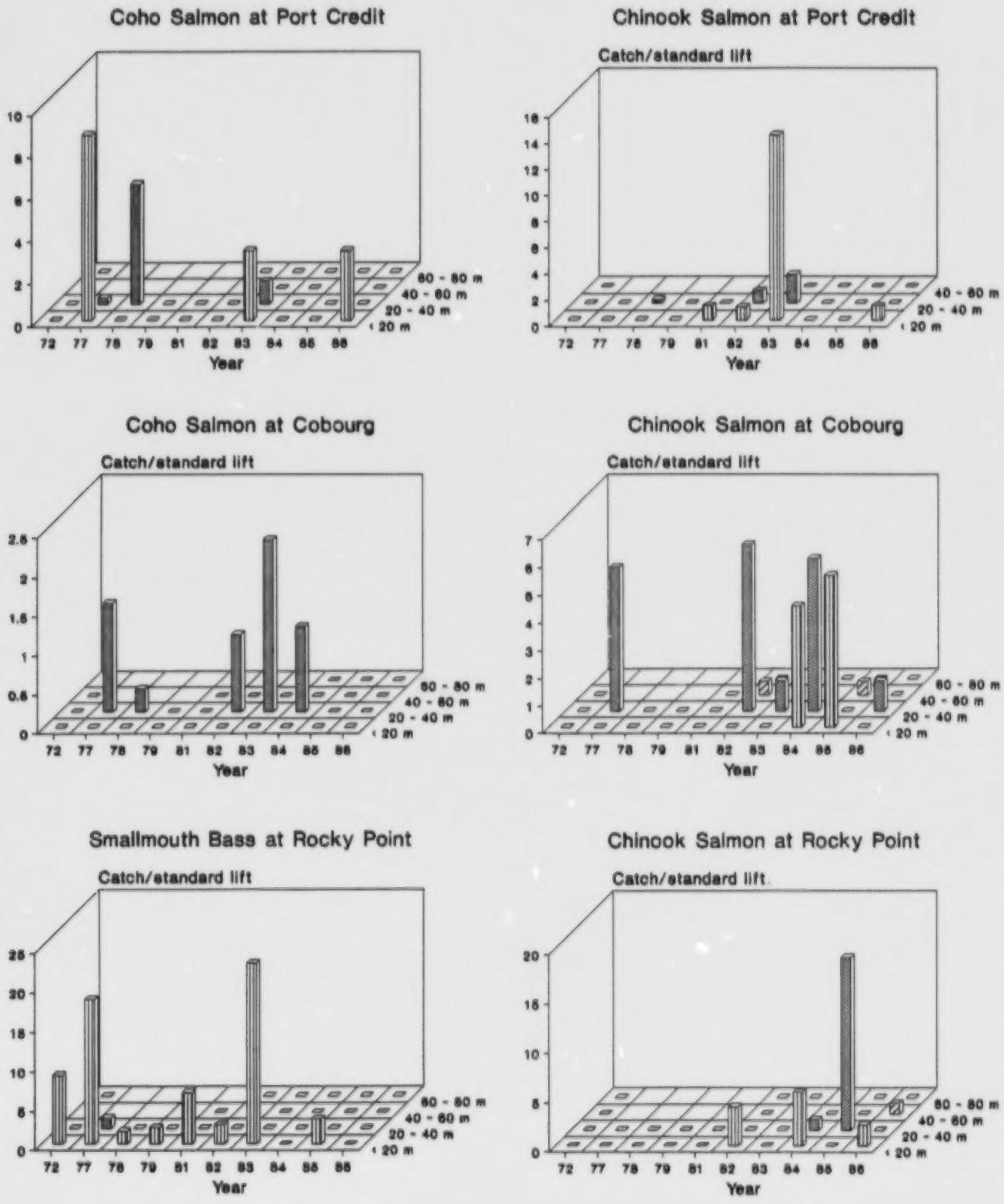
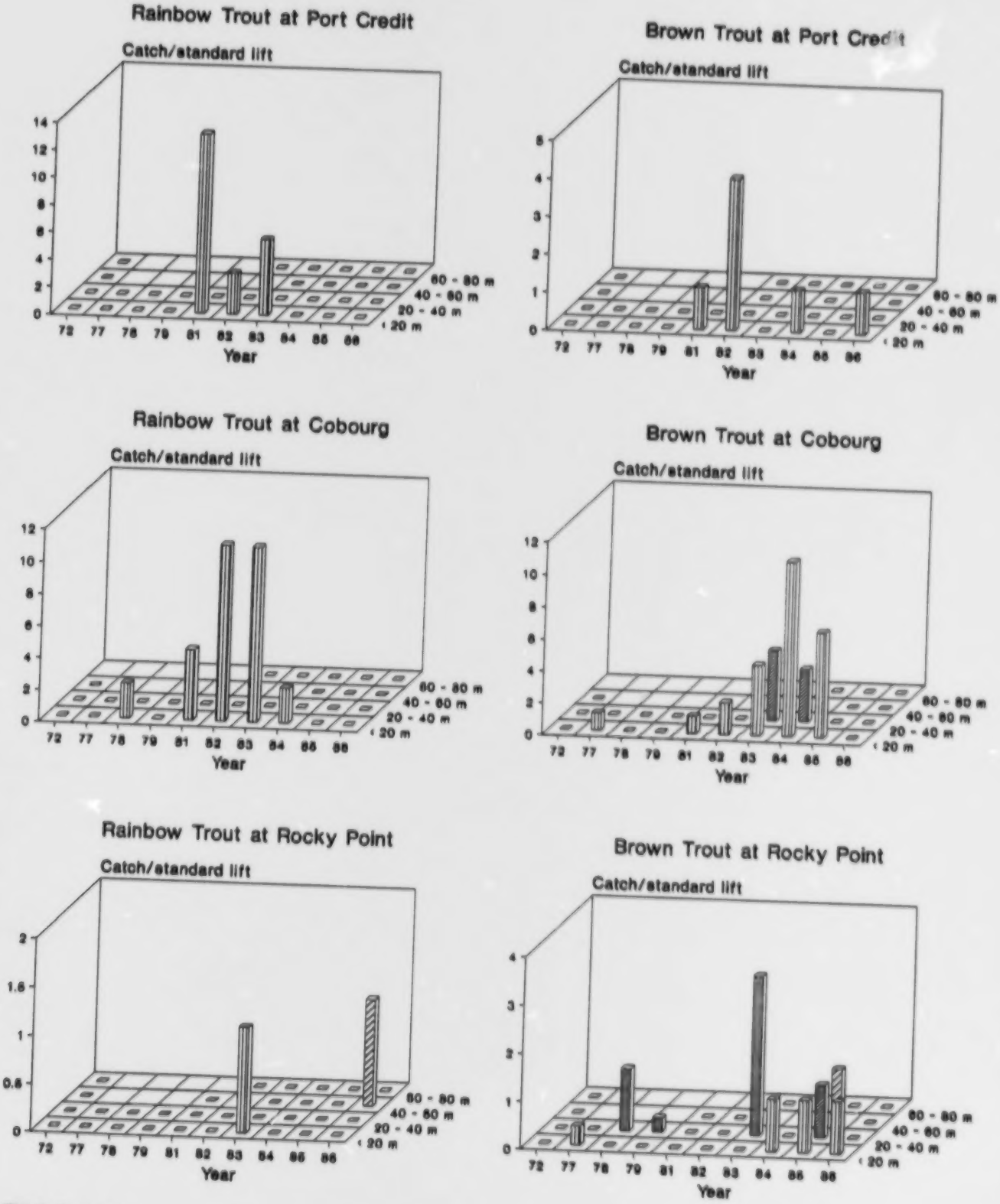

Coho Salmon at Port Credit
Chinook Salmon at Port Credit
Catch/standard lift
Coho Salmon at Cobourg
Chinook Salmon at Cobourg
Smallmouth Bass at Rocky Point
Chinook Salmon at Rocky Point
60 - 80 m
40 - 60 m
20 - 40 m
< 20 m
72 77 78 79 81 82 83 84 85 86
Year

FIG. 3. Continued.



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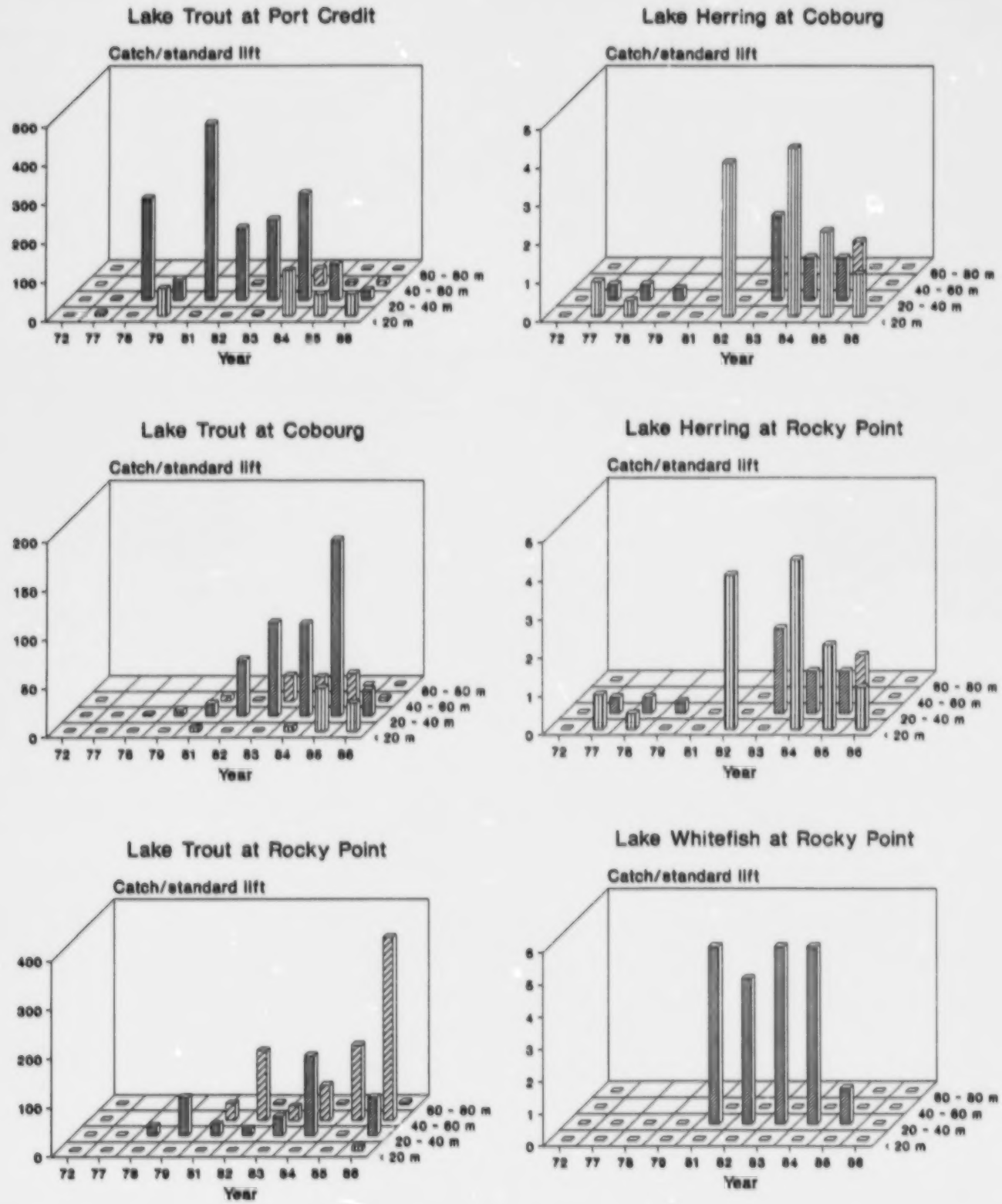

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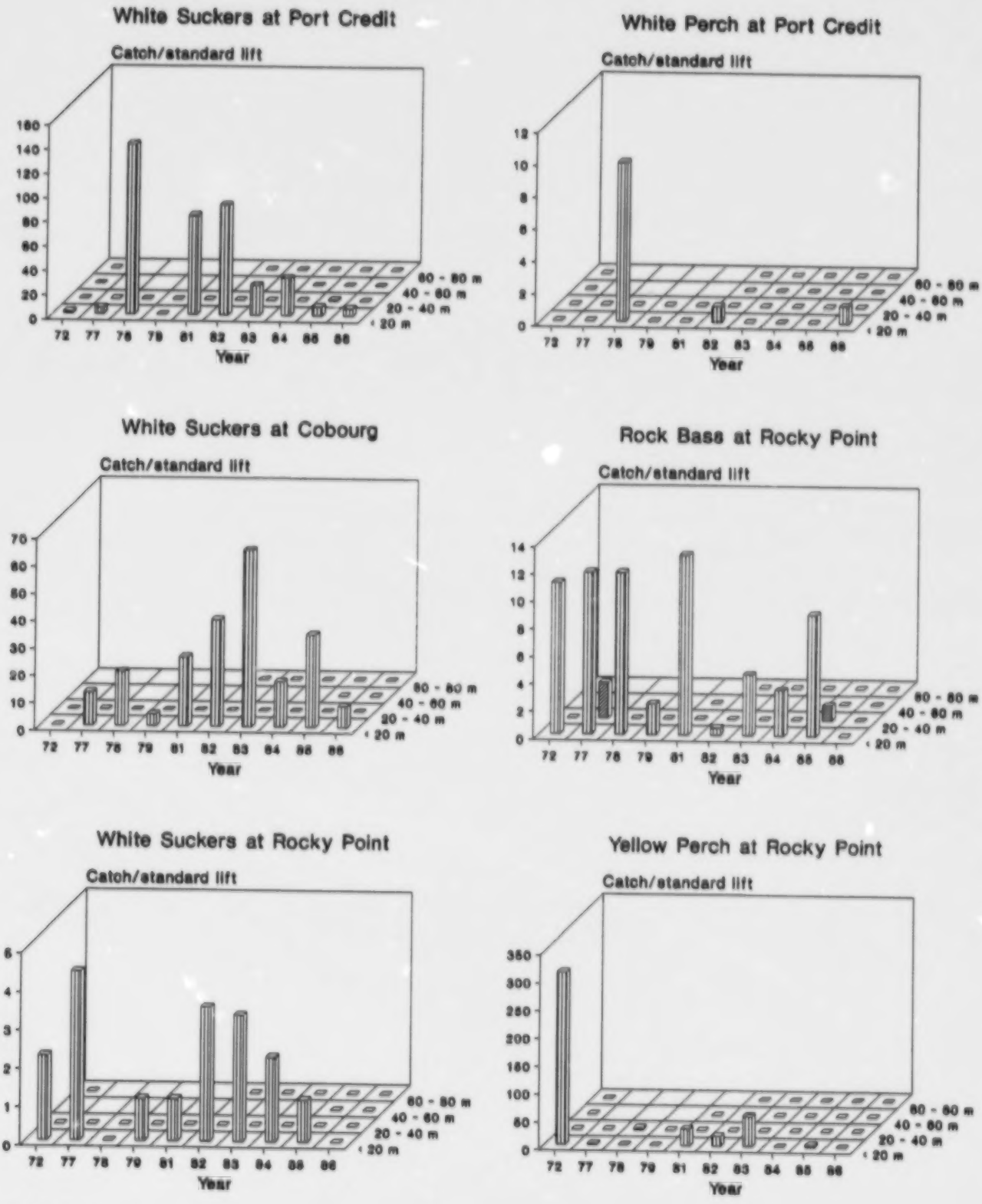

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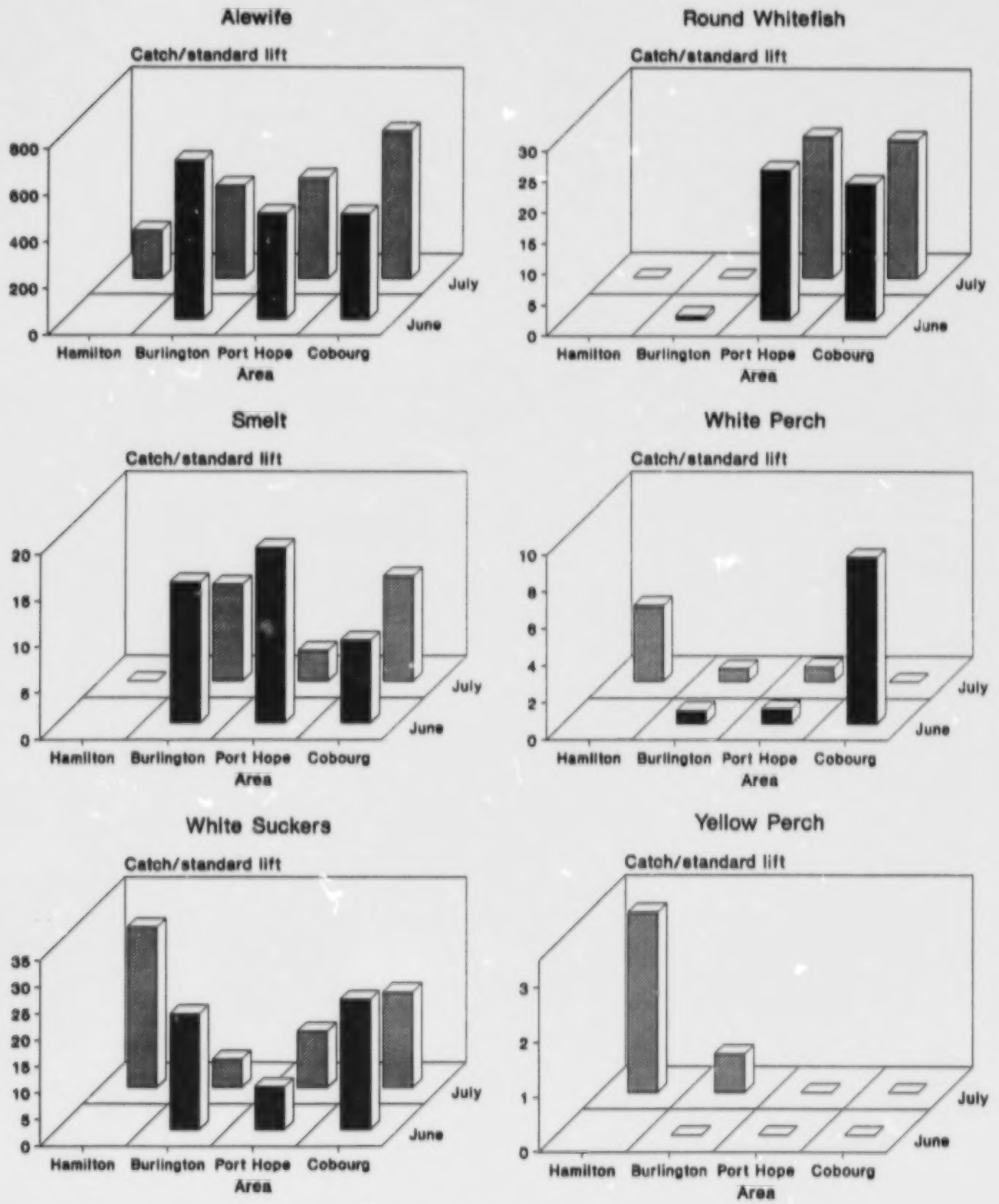

FIG. 4. Catch rates of index gillnets in Lake Ontario in June and July, 1990 by depth.

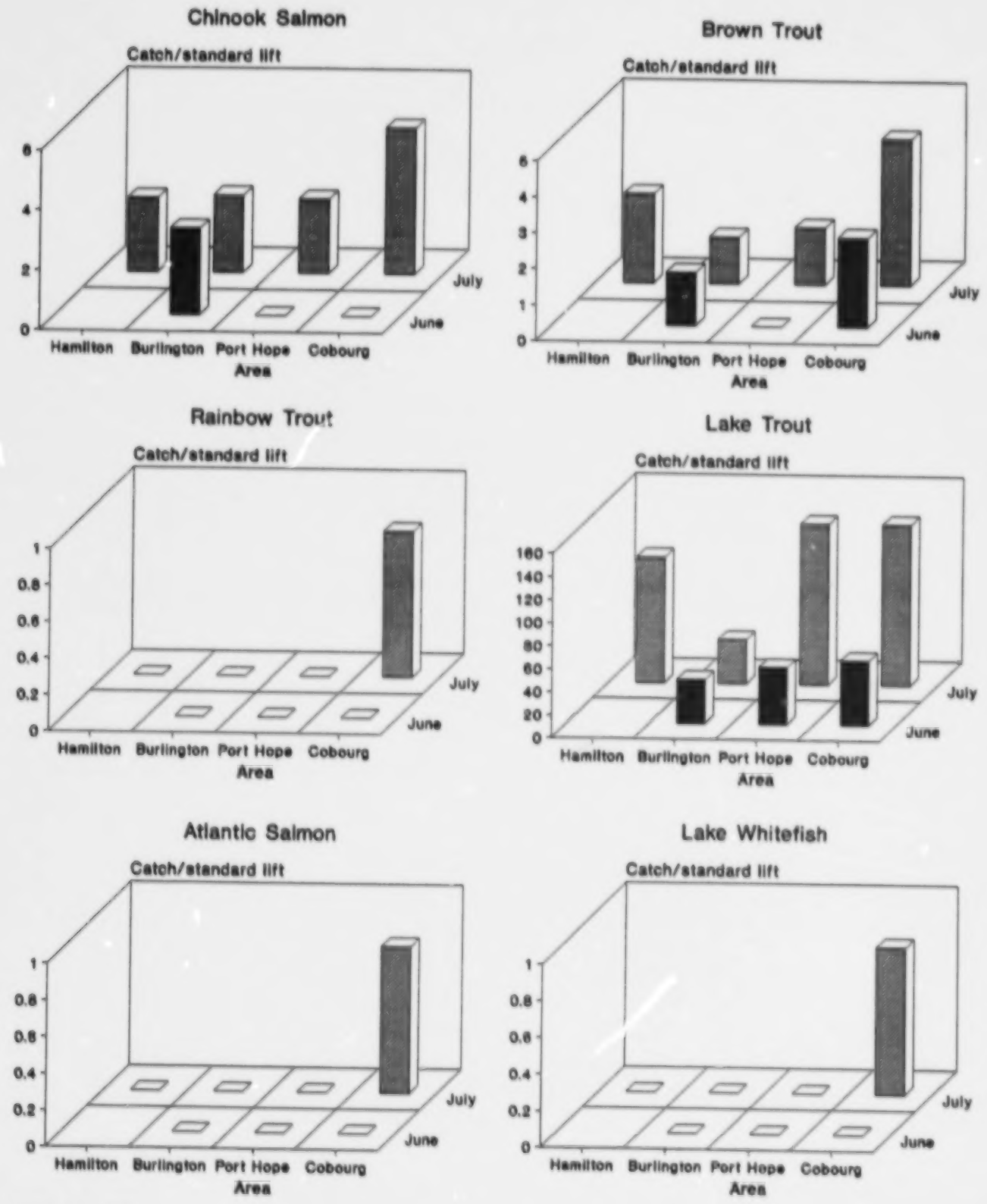

FIG. 4. Continued.

Estimates of the Total Angling Harvest in the Canadian Waters of Lake Ontario in 1989

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Lake Ontario Fisheries Unit, 1990 Annual Report LOA 91.1 (Chapter 8)

This report estimates the magnitude of various components of the angling fishery in the Canadian waters of Lake Ontario in 1989 by using historical angler surveys, the size of migratory salmonid spawning runs, salmonid stocking trends, and anecdotal information from OMNR District staff. The total 1989 angling effort associated with the Canadian part of Lake Ontario was estimated at 845,000 angler days, resulting in a harvest of 613,000 fish or 1,450,000 kg. Salmonids accounted for 87% of the harvest by weight; walleye accounted for 10%, and the remainder were warmwater species. Fifty-three percent of the salmonid fishing effort has not been recently surveyed, and most of this represents the lakeshore fishery and the stream fishery for migratory fish.

Recommendations

Validate the estimates of harvest and effort, herein, by conducting the angler surveys outlined in the Lake Ontario Fisheries Unit (LOFU) Assessment Operational Plan:

a) a launch daily boat angler survey in western Lake Ontario on an annual basis;

b) a lakewide charter boat angler-effort survey on an annual basis, and

c) lakeshore, stream, marina (including charter boats) and eastern outlet basin angler surveys on a 5-yr rotational basis.

Introduction

The Lake Ontario angling fishery is believed to be among the largest in the Province of Ontario. The salmonid component of that fishery is found throughout the main body of the lake and in a large number of the tributary streams. As well, a substantial walleye angling fishery is located in the Bay of Quinte. There exists a large information gap, in that, there has never been a comprehensive angler survey of lakeshore and stream fishing activity based on Lake Ontario fish. This report attempts to fill in these gaps with harvest and effort estimates at a level of precision that is useful for planning purposes.

Methods

Angler surveys from 1989, for the Bay of Quinte and for the boat fishery in the Canadian waters of western Lake Ontario (west of Salmon Point), provided a fairly accurate basis to which estimates of effort and harvest of the remaining components of the fishery was added. The general approach for making these estimates was to use data from historical surveys, and expand the results of these surveys through time and/or space (see reports in Bibliography). The expansions were based on growth of the boat fishery, increases in stocking, the relative size of migratory runs or personal observations of OMNR District Staff. Current estimates of the size of salmonid migratory spawning runs in Lake Ontario tributary streams were obtained from OMNR fishway monitoring, stocking records, and personal observations of OMNR District Staff. The following briefly describes how expansions were made for various components of the fishery, and the assumptions made in the generation of the 1989 estimates of effort and harvest.

Boat Fisheries

April to September boat angler data were from a 1989 LOFU survey of all components of the boat angler fishery (launch daily, charter and unguided marina boats) for western Lake Ontario. No expansions from the reported results were required.

December to April Pickering Nuclear Generating Station (NGS) data was from a 1988/89 survey of fair weather boat anglers fishing in the immediate vicinity of the power plant. No expansions were made to reported results. However, fishing effort on poor weather days was not reported.

May to September eastern outlet basin data was from a 1987 LOFU survey of boat anglers. An expansion factor, based on the increase in charter boat effort in the central basin fishery from 1987 to 1989, was applied to estimate the 1989 eastern outlet basin angler activity.

Bay of Quinte open water and ice fishing activities were based on LOFU angler surveys conducted in 1989. These surveys covered a portion of the year, and were expanded based on the monthly distribution of effort in 1988. These estimates excluded East Lake, West Lake, and Weller's Bay, all of which should functionally be included with Lake Ontario, and the Bay of Quinte.

Lakeshore and Stream Fisheries

Niagara District estimates of lakeshore fishing activity was based on a fall 1981 District survey which included

Lake Ontario and the lower Niagara River. For the salmonid component of that fishery an expansion factor, proportional to the increased rate of salmonid stocking (exclusive of lake trout), was applied to estimate the 1989 angler fishery. The other (warmwater) component of the lakeshore fishery was assumed to have been unchanged since 1981. The spring lakeshore fishery was assumed to be 1.5 times the fall fishery.

Cambridge District stream fisheries estimates were based on a 1983 fall angler survey of the Credit River (in Maple District). The relative rates of salmonid stocking, exclusive of lake trout, were used to extrapolate to 1989. The relative rates of stocking between the Credit River and Bronte Creek were used to extrapolate Maple District data to Cambridge District. These are believed to be conservative numbers since no estimates could be made of the other rivers, and lakeshore fisheries in Cambridge District. The spring stream fishery was assumed to be equal to that of the fall stream fishery.

The Maple District stream fishery was estimated from a 1983 fall angler survey of the Credit River. The relative rates of Pacific salmon stocking in the Credit River were used to extrapolate to 1989 for the Credit River. The relative rates of all salmonid stocking in the Credit River as compared to all other Lake Ontario waters within Maple District were used to estimate the fishery for other rivers and shorelines in the district. The spring stream fishery was assumed to be equal to the fall fishery.

The Ganaraska River angling estimates were based on angler surveys conducted by Lindsay District during fall 1986 and spring 1980. These surveys were extrapolated to 1989 based on the relative size of the rainbow trout runs in the Ganaraska. All other stream fisheries in Lindsay District were assumed to be double the sum of the spring and fall fisheries for the Ganaraska.

No estimates for lakeshore or stream angling in Napanee District were available, and so these fisheries are not included here. However, based on our own observations and conversations with District staff we feel that these fisheries are smaller in Napanee than the other Lake Ontario districts.

Results and Discussion

Lakewide 1989 angling effort was estimated at 845,000 angler-days (1 angler-day = 4 rod-hr) resulting in the harvest of almost 613,000 fish or 1,450,000 kg (Table 1). Salmonids accounted for 87% of this harvest by weight, and walleye and other warmwater species accounted for another 10 and 3% respectively. These estimates were biased low because we have not been able to make reasonable estimates for some fisheries. However, the excluded fisheries were almost negligible compared to the total estimates of effort and harvest.

Fifty-three percent of the Lake Ontario salmonid fishing effort has not been recently surveyed. Of the fisheries not surveyed in 1989, most were lakeshore and stream based, but the summer boat fishery in the eastern outlet basin also accounted for a small portion. Although the 1987 eastern outlet basin boat fishery was small compared to the sum of all fisheries in that year, it represented the bulk of the lake trout angling harvest for Canadian waters of Lake Ontario. Without measurements of these components of the fishery a complete assessment of Ontario's stocking program in Lake Ontario was not possible.

Management Prognosis

The salmonid boat fishery in western Lake Ontario and the walleye fishery in the Bay of Quinte have stabilized in terms of catch and effort. Barring any environmental or community catastrophes (e.g. from zebra mussels, or alewife winter kills) we foresee little change in these fisheries.

Particular stream fisheries (e.g. Ganaraska River) are dependent on natural reproduction more than the lake fishery. If natural reproduction of Lake Ontario salmonids continues to improve in some of these streams then their fisheries should improve, in turn.

Anecdotal information suggests that the lake trout and brown trout fisheries in the eastern outlet basin continue to grow. Our index gillnets in the eastern outlet basin suggests some habitat overlap of brown trout and walleye. Based on these nets we believe that walleye populations in some parts of the basin are high enough to attract angling pressure. Moreover, with the increasing angling effort directed towards brown trout, we believe that these walleye may be located by anglers in the next few years. When that occurs reduction of harvest from other components of the walleye population may have to be considered.

Similarly, the rebounding Bay of Quinte whitefish may be vulnerable to ice anglers. If whitefish are targeted by anglers then stricter harvest regulations may be necessary.

Acknowledgments

Thanks to Tom Stewart, Steve Kerr and Ron DesJardine for critical review and to Carol Ward for copy editing and Linda Balsillie for publishing of this paper.

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TABLE 1. Summary of 1989 estimated angler-effort (1-angler-day = 4 rod-hr) and harvest for Canadian waters of Lake Ontario and Bay of Quinte.

District	Season	Component of fishery	Angler effort (days)	Species group	Number of fish (kg)	Mean fish wt.	Harvest (kg)
Niagara	Apr/Sep	All boats	53,100	Salmonids	15,100	4.5	68,000
	Jan/May	Stream/shore spring	29,100	Salmonids	7,000	3.0	20,900
				Other	8,100	0.3	2,400
	Sep/Dec	Stream/shore fall	19,400	Salmonids	4,600	4.0	18,500
				Other	5,400	0.3	1,600
		Total	101,600	Salmonids	26,700	4.0	107,400
				Other	13,500	0.3	4,000
Cambridge	Apr/Sep	All boats	76,600	Salmonids	33,000	4.5	148,400
	Spring	Stream/shore	26,700	Salmonids	12,200	3.0	36,600
	Fall	Stream/shore	19,000	Salmonids	8,700	5.4	46,800
		Total	122,300	Salmonids	53,900	4.3	231,800
Maple	Apr/Sep	Boats	140,400	Salmonids	67,400	4.5	303,100
	Dec/Apr	Pickering NGS boats	1,400	Salmonids	2,000	1.4	2,800
				Walleye	200	1.8	300
				Other	1,300	0.3	400
	Mar/Apr	Credit River stream/shore	30,000	Salmonids	13,700	3.0	41,000
	Oct/Dec	Credit River stream/shore	30,000	Salmonids	13,700	5.4	74,000
	Spr/Fall	All other stream/shore	25,600	Salmonids	11,700	3.0	35,000
		Total	227,400	Salmonids	108,500	4.2	455,900
				Walleye	200	1.9	300
				Other	1,300	0.3	400
Lindsay	Apr/Sep	All boats	48,100	Salmonids	34,200	4.5	153,900
	Mar/May	Ganaraska River stream/shore	26,600	Salmonids	12,500	3.0	37,400
	Sep/Nov	Ganaraska River stream/shore	13,300	Salmonids	6,200	3.1	19,600
	Spr/Fall	All other shore anglers	79,700	Salmonids	37,400	3.0	112,300
		Total	167,700	Salmonids	90,300	3.6	323,200

TABLE 1. (Continued)

District	Season	Component of fishery	Angler effort (days)	Species group	Number of fish (kg)	Mean fish wt.	Harvest (kg)
Napanee	Apr/Sep	Western/central basin boats	38,100	Salmonids	24,000	4.5	107,800
	May/Sep	Kingston basin boats	15,400	Salmonids	12,600	3.4	42,700
				Other	3,000	1.1	3,300
	May/Nov	Bay of Quinte boats	120,700	Walleye	134,200	0.8	105,000
				Other	65,400	0.3	22,800
	Jan/Feb	Bay of Quinte ice	51,900	Walleye	19,100	1.7	33,300
				Other	60,100	0.2	13,300
		Total	226,100	Salmonid	36,600	4.1	150,500
				Walleye	153,300	0.9	138,300
				Other	128,500	0.3	39,400
ALL		TOTAL	845,100	Salmonid	316,000	4.0	1,268,800
				Walleye	153,500	0.9	138,600
				Other	143,300	0.3	43,800
				ALL	612,800	2.4	1,451,200

Alewife and Smelt Catches in Midwater Trawls During the 1990 Survey of Lake Ontario

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A midwater trawl survey was used to make the first lakewide estimates of alewife and smelt abundance in Lake Ontario. Hydroacoustic data showed that substantial numbers of prey fish avoided the trawl, so absolute estimates of abundance were inaccurate. However, estimates are valuable as an index of abundance for both YOY and older prey; catch variance suggested that a summer midwater survey can provide the same precision as bottom trawl surveys, but over a larger area. The midwater survey methodology can provide fairly precise estimates of adult prey abundance as well as provide indices of YOY abundance.

Recommendations

1. Continue the program for trend-through-time abundance indices of alewife and smelt abundance.
2. The stratification (by location and limnological zone) of this survey is appropriate for the time of year and level of sampling effort and should be maintained.
3. Continue to evaluate approaches to improving precision of YOY estimates.
4. Do not use the midwater beam trawl for ground truthing hydroacoustic data since alewife and smelt do not appear to be equally succeptable to capture in this gear.

Introduction

Alewife (*Alosa pseudoharengus*) and smelt (*Osmerus mordax*) are the major prey of salmonids in Lake Ontario (Brandt 1986; Plante et al. 1991). High levels of salmonid stocking (Savoie and LeTendre 1991) and increasing numbers of naturally reproduced salmonids (Bowlby 1991) are certain to maintain high numbers of predators for the near future. To maintain stable, healthy prey stocks, the density of salmonid predators must be compatible with the production of prey populations. If fisheries managers are to achieve this balance between predators and prey, they require accurate and timely assessments of Lake Ontario's fish community.

Bottom trawling surveys for alewife and smelt have been conducted throughout U.S. waters since 1978 (O'Gorman et al. 1991). Surveys in Canadian waters were limited to an area between the Niagara River and Toronto because substrate is not suitable elsewhere (Mathers 1991).

Midwater trawling has the advantage of not being limited by substrate morphometry. The technique also provides coverage of pelagic components of alewife and smelt populations. Fish managers identified absolute estimates of prey abundance as an essential requirement to effectively manage Lake Ontario's fish community; midwater trawling has the potential for providing this type of information.

In previous years, midwater trawling projects provided details on methodology and the distribution of prey species in the water column (Schaner et al. 1990). Objectives for the 1990 program were: (1) obtain lakewide estimates of alewife and smelt relative abundance, (2) generate an index of young-of-year (YOY) abundance for both prey species, and (3) attempt to estimate absolute prey abundance by using hydroacoustics in conjunction with midwater trawling. This report provides results of the trawling program.

Methods

Seven geographic sampling locations were selected based on general morphology of the lake basin, and to allow comparison to other prey fish surveys (Fig. 1). Three limnological strata (epilimnion, metalimnion, and hypolimnion) were selected based on alewife and smelt summer distributions reported by Schaner et al. (1990). Samples were taken randomly from within locations and limnological strata (Table 1). A stratified random design was used to estimate lakewide abundance and measure sampling error.

One hundred and fifteen midwater tows were completed at night (from 2127 to 0508 hr) between July 20 and August 31, 1990. Tows were 20 min long at a vessel speed of 2 kn, starting when the net reached the target depth and ending when retrieval began. In the U.S. east

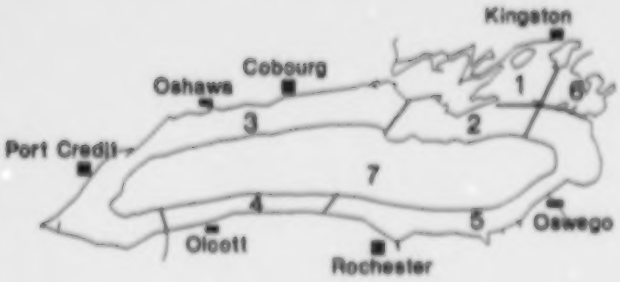

FIG. 1. Map of Lake Ontario showing the locations used in the 1990 midwater trawling surveys. 1 = Canadian east, 2 = Canadian central, 3 = Canadian west, 4 = U.S. west, 5 = U.S. central, 6 = U.S. east, 7 = offshore location (bottom depth > 79 m).

TABLE 1. Volume (km^3) and number of midwater trawls for each location used in the 1990 survey of Lake Ontario. Volumes presented, represent only water < 80 m depth. The offshore location refers to all water > 79 m. Note that the water column in the U.S. central location was not stratified due to upwelling.

Location	Volume (km^3)	Epilimnion trawls	Metalimnion trawls	Hypolimnion trawls
Canadian east	19	5	3	1
Canadian central	76	5	3	3
Canadian west	137	12	14	8
U.S. west	25	8	6	2
U.S. central	75			20
U.S. east	12	3	3	2
Offshore	1331	8	7	2

and U.S. central locations, tows were made from the RV Seth Green, while the other tows were made from the RV Steelcraft. The midwater trawl was 3 m wide, 3 m high and 11.8 m long with a 1/2 in stretched mesh codend. Metal pipe was attached along the top and the bottom of the trawl mouth to maintain a 2.7 m horizontal opening. The vertical opening of the net (2.3 m) was maintained through floats attached to the top bar and weights attached to the bottom bar. The net was towed by a single cable, with bridles running to the four corners of the net's mouth. More details on the trawl construction are described by Gjernes (1979).

Exact towing locations and limnological zones were selected before the survey (Fig. 1). Station depths were randomly chosen from within the locations. Temperature profiles were taken at each station to determine boundaries between the limnological zones. Trawling depth was randomly selected from within the desired limnological strata. Trawls were limited to between 2 m below the surface and 7 m above the bottom. Towing depth and vertical opening was monitored with net recorders using acoustic links.

Captured fish were separated by species and then counted and weighed in aggregate. Total lengths were recorded for all fish to the nearest 5 mm. Total length, weight, otoliths and scale samples were taken for a subsample of fish from each location but have not been examined at this time.

The surface area of Lake Ontario was determined by cutting a map along the depth contours and weighing the pieces (Lind 1974). Volume of each limnological strata was determined within each location using the depth of the thermocline, observed during the sampling. The total volume calculated using this method was 1675 km^3, which is very similar to the total volume calculated by the U.S. National Oceanic and Atmospheric Administration (1640 km^3, Chart NOAA, HO 26-611(11-71)).

Catch-per-unit-effort (CUE), for each strata, was expressed as the average number of fish caught per 20 min tow. No CUE's were calculated for the epilimnion and metalimnion at the U.S. central location, since an extensive upwelling of hypolimnetic water occurred along the U.S. shore during the sampling period. Estimates of smelt and alewife abundance, along with 95% confidence intervals, were made using a stratified random sampling design (Bazigos 1974), i.e. expanding strata average catches by the number of volume units in each strata.

Results

Catch Rates in Midwater Trawls

Catches in the midwater beam trawl were dominated by alewife and smelt, making up 46 and 52%, respectively, of the total catch of all species (Table 2). The alewife caught ranged in total length between 22 and 189 mm (Fig. 2) while smelt ranged between 17 and 179 mm (Fig. 3). After examining the length frequency distributions, alewife less than 80 mm and smelt less than 65 mm total length were classified as YOY. The mean weight of the YOY alewife and smelt were 0.1 and 0.3 g respectively. The mean weight of the older alewife and smelt were 19.4 and 7.1 g respectively.

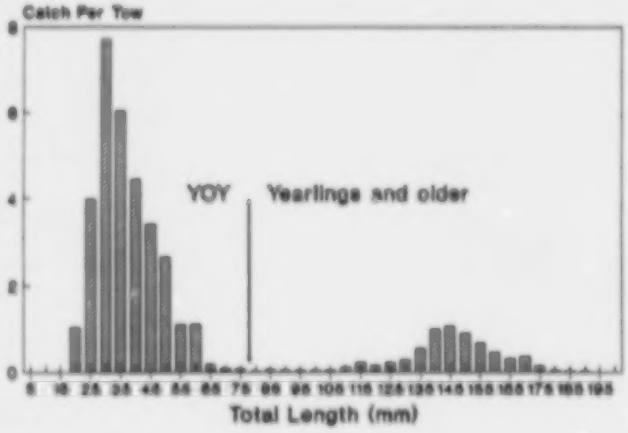

FIG. 2. Total length (mm) distribution of alewife caught during the 1990 midwater trawling survey on Lake Ontario.

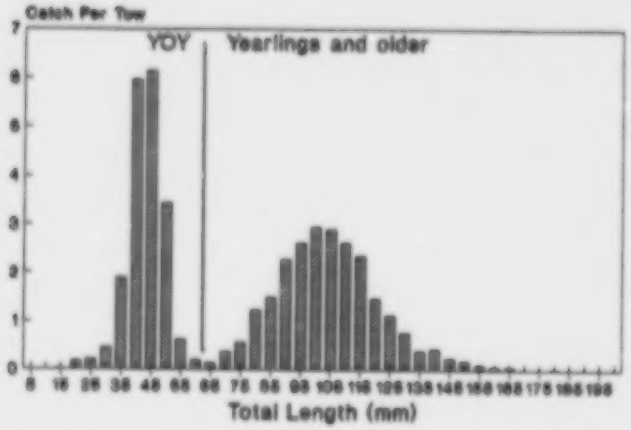

FIG. 3. Total length (mm) distribution of smelt caught during the 1990 midwater trawling survey on Lake Ontario.

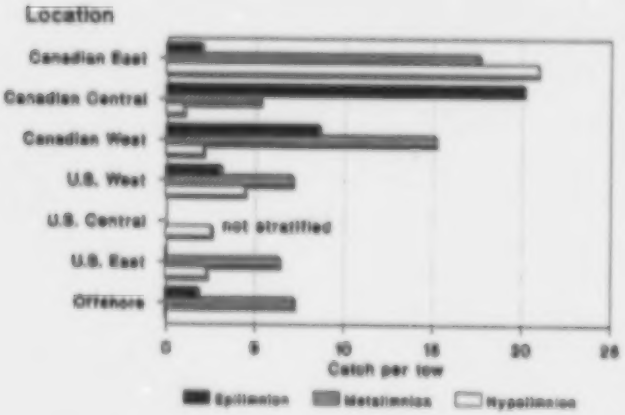

FIG. 4. Mean catch (# fish per 20 min trawl) of older alewife in the limnological and location strata sampled during the 1990 midwater trawling survey on Lake Ontario. Note that no thermocline was present inthe U.S. central location.

To examine the validity of our stratification scheme, catches were compared between the location and limnological strata using a two-factor ANOVA on the log-transformed data. Tukey multiple comparisons were performed, when appropriate, to compare stratum means. The data from the U.S. central location were excluded from this analysis because only hypolimnetic water was available.

Older Alewife

Catches of older alewife in the metalimnion were significantly higher than the other zones while the catches in the epilimnion and hypolimnion were not significantly different from each other (Table 3, Fig. 4). Although alewife catches were 3 times greater along the north shore, differences in the catches due to locations were not significant. Catches in the U.S. central location (not included in the ANOVA) tended to be low.

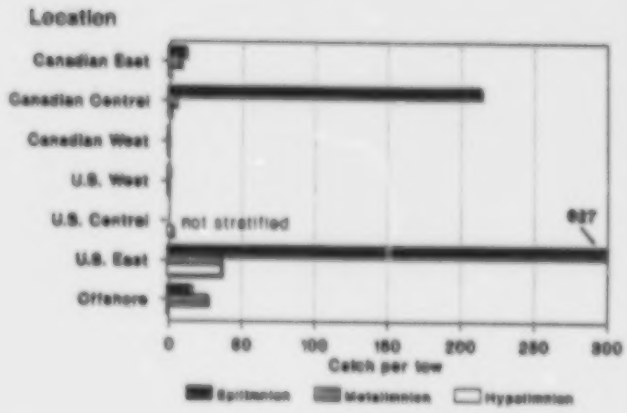

FIG. 5. Mean catch (# fish per 20 min trawl) of YOY alewife in the limnological and location strata sampled during the 1990 midwater trawling survey on Lake Ontario. Note that no thermocline was present in the U.S. central location. Also, the catches in the U.S. eastern location in the epilimnion had an average of 627 fish per tow.

YOY Alewife

Very strong differences in the catches of YOY alewife were apparent among locations and among limnological strata (Table 3, Fig. 5). However, the relationship among the limnological strata was not the same for all locations. The smallest catches were observed in the U.S. west and Canadian west and a secondary ANOVA showed that at these locations there were no significant differences among the limnological strata. For the remaining locations, a secondary ANOVA showed that the catches in the epilimnion were significantly higher than those in the hypolimnion, while catches in the metalimnion were not different from the other two limnological strata. Of these locations the highest catches tended to be in the U.S. eastern and Canadian central locations. The Canadian east, offshore, and U.S. central locations had medium sized catches.

Older Smelt

Catches in all three limnological zones where significantly different from each other (Table 3, Fig. 6). They were highest in the metalimnion, and lowest in the epilimnion. Of the locations compared, the offshore had the lowest catches, while all other locations were not significantly different. Catches in the U.S. central location (not included in the ANOVA) tended to be low.

YOY Smelt

There were significant differences among locations and limnological strata in the catches of YOY smelt (Table 3, Fig. 7). However, the relationship among the catches in the limnological strata was not the same for all locations. The highest catches tended to be in the U.S. east and Canadian east; the lowest in the U.S. west and the Canadian west. In general, catches were highest in the epilimnion and lowest in the hypolimnion. However, in the U.S. east and U.S. west locations, catches in the metalimnion were higher than in the epilimnion. The mean catch in the U.S. central location (not included in the ANOVA)

TABLE 2. Catch summary (# fish/20 min trawl) for all species by location from midwater trawling in Lake Ontario during the summer of 1990. The catches of alewife and smelt are separated into young of year (YOY) and older (Older) fish.

Species	Canadian east	Canadian central	Canadian west	U.S. east	U.S. central	U.S. west	Offshore
YOY alewife	9.3	99.4	0.2	258.1	3.5	0.6	19.1
Older alewife	9.3	10.9	9.8	3.0	2.6	4.8	3.9
YOY smelt	6.3	5.9	1.0	30.8	65.7	3.7	24.6
Older smelt	61.4	14.6	30.3	36.1	12.6	25.9	4.2
Chinook salmon	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Lake trout	0.1	0.0	0.0	0.3	0.0	0.1	0.0
Lake herring	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Emerald shiner	0.0	0.0	0.0	0.1	0.0	0.0	0.0
American eel	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Threespine stickleback	0.0	3.8	0.2	0.3	1.3	0.0	3.6
Trout-perch	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Johnny darter	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Sculpin family	0.0	0.0	0.0	0.0	0.3	0.0	0.0

TABLE 3. Results of two-way factorial ANOVA's comparing catches in midwater frame trawls during the 1990 survey on Lake Ontario. Locations, limnological strata and their interaction term were all considered as sources of variation. Shown are the degrees of freedom (df), "F" statistic, and significance probability (in brackets).

Source of Variation	df	Older alewife	YOY alewife	Older smelt	YOY smelt
Location strata	5	1.92 (0.1009)	20.24 (0.0001)	8.15 (0.0001)	5.04 (0.0005)
Limnological strata	2	6.32 (0.0001)	10.10 (0.0001)	49.14 (0.0001)	3.48 (0.0356)
Location * limnological strata	10	1.41 (0.1909)	3.62 (0.0006)	2.24 (0.0234)	2.28 (0.0215)

TABLE 4. Estimated abundance (millions of fish) and 95% confidence limits for alewife and smelt in August, 1990 in Lake Ontario. Separate estimates were made for young of the year (YOY) and older (Older) fish. Estimates are based on catches in midwater beam trawls and are prone to the biases of this gear (see text). The offshore data (>79 m) were divided up and added to the six nearshore locations for comparative purposes.

Basin	Older alewife	YOY alewife	Older smelt	YOY smelt
Canadian east	20	19	91	16
Canadian central	102	1,008	97	59
Canadian west	68	1	337	6
U.S. west	13	2	45	5
U.S. central	26	34	124	650
U.S. east	4	613	23	22
Offshore	70	379	68	529
Whole Lake	303 (+/-49%)	2,056 (+/-55%)	785 (+/-38%)	1,287 (+/-66%)

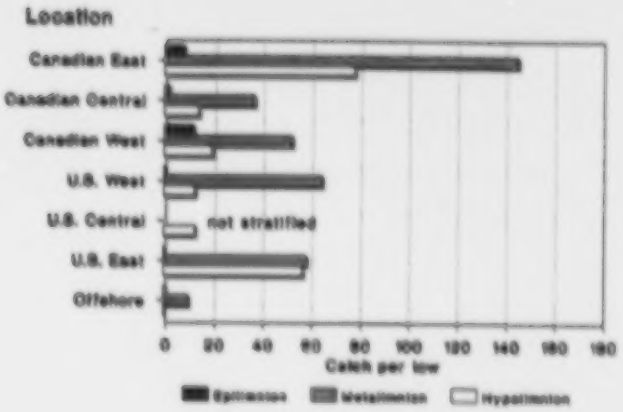

FIG. 6. Mean catch (# fish per 20 min trawl) of older smelt in the limnological and location strata sampled during the 1990 midwater trawling survey on Lake Ontario. Note that no thermocline was present in the U.S. central location.

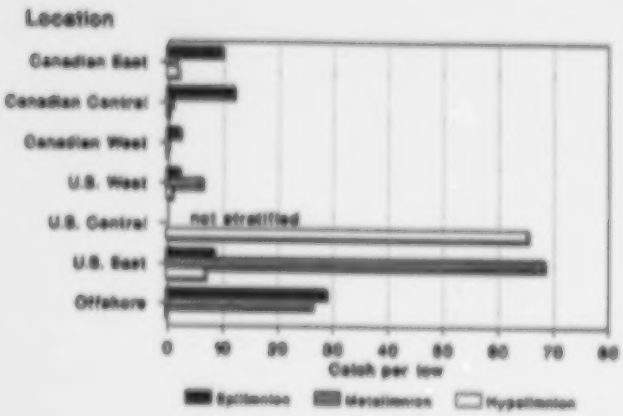

FIG. 7. Mean catch (# fish per 20 min trawl) of YOY smelt in the limnological and location strata sampled during the 1990 midwater trawling survey on Lake Ontario. Note that no thermocline was present in the U.S. central location.

was relatively high, but there were large differences between trawls.

Abundance Estimates

Trawl catch results indicated that 303 million alewives and 785 million smelt, yearlings and older, were extant in Lake Ontario during the summer of 1990; 95% confidence limits for these estimates were +/- 49 and +/- 38%, respectively. YOY estimates (and 95% C.L.) were 2.1 billion (+/- 55%) and 1.3 billion (+/- 66%) for alewives and smelt, respectively.

The abundance of older smelt in the area between Toronto and the Niagara River are estimated annually in bottom trawling surveys conducted jointly by Ontario Ministry of Natural Resources (OMNR) and United States Fish and Wildlife Service (USFWS)(Mathers 1991). The 1990 bottom trawling estimate was 305 million older fish. The abundance estimate for this same area using the midwater beam trawl during August 1990 was 115 million older smelt.

The USFWS and New York State Department of Environmental Conservation (NYDEC) jointly conduct annual bottom trawling surveys of smelt (during early June) and alewife (during late April-early May) (O'Gorman et al. 1991). The estimates of smelt for all U.S. waters for 1990 was 394 million older fish (R. Owens, USFWS, 17 Lake St., Oswego, N.Y. 13126, pers. comm.). The abundance estimate for this same area using the midwater beam trawl during August 1990 was 248 million older smelt.

The spring bottom trawl estimates of alewife for all U.S. waters for 1990 was 1,460 million older fish (R. O'Gorman, USFWS, 17 Lake St., Oswego, N.Y. 13126, pers. comm.). The abundance estimate for this same area using the midwater beam trawl during August 1990 was 94 million older smelt. The midwater trawling estimate for the whole lake was 303 million older fish.

Discussion

YOY Catches

Relatively few YOY alewife and YOY smelt were caught in the midwater trawls during 1989. The increase in 1990 could be related to the program running later in the summer or the location trawled in 1989 could have had fewer YOY fish present than it did in 1990. Strong differences among locations existed in the 1990 data, for instance, catches of YOY alewife were much lower in western Lake Ontario. This could be due to differences in spawning success among the locations or to spring distribution of adults. An alternative hypothesis is that YOY alewife in the west were smaller and/or occupied waters which made them less vulnerable to trawling.

YOY prey do not inhabit the same limnological strata as older adults during the late summer. The highest catches of older alewife were in the metalimnion while YOY were highest in the epilimnion. Brandt (1980) found similar differences in the distributions of YOY (17-20°C) and older alewife (11-14°C) in Lake Michigan. This relationship also tended to be true for smelt at some locations in Lake Ontario, but not others.

Yearling and Older Prey

The estimate of 303 million older alewives lakewide is far below our expectations. The number of alewife observed in the 1990 bottom trawling survey in U.S. waters was 16 times larger than the number estimated from the midwater survey over the same area and in fact 5 times larger than the number estimated from the midwater survey for the whole lake. The number of smelt observed in the 1990 bottom trawling survey in U.S. waters was 2 times larger than the number estimated from the midwater survey for U.S. waters. The number of smelt observed in the 1990 bottom trawling survey in Canadian waters between the Niagara River and Toronto was 3 times larger than the number estimated from the midwater survey for that area.

Midwater trawling does not appear to catch all available alewife. Smelt catches were also low but closer to bottom trawling results than those for alewife. Migration and predation during the time between the bottom trawling and the midwater surveys may account for some of the differences observed. However, differences observed between the surveys cannot be accounted for by these factors alone.

Hydroacoustic data were collected concurrently with 23 of the trawls in the Canadian west location, and these results suggest that alewives were avoiding the midwater trawl (Schaner and Mathers 1991). Dual beam target densities for all fish in the water column were significantly correlated to the abundance of alewife observed for trawls in the epilimnion. However, the acoustic densities were 25 times larger than the trawl densities. Smelt catches were unrelated to the hydroacoustic densities but were of similar magnitude. This suggests that alewives were more abundant than smelt and they were caught in proportion to their abundance. Since the alewife catches in the midwater trawl were lower than smelt catches (except in the epilimnion), this suggests that smelt are more susceptible to capture than alewife, with this type of trawl.

We conclude that midwater trawl estimates of absolute abundance for both alewife and smelt are not accurate. Furthermore, because alewives and smelt are not equally vulnerable to the trawl, summer catches with the 3 X 3 midwater frame net should not be used to apportion hydroacoustic abundance estimates. Perhaps another time of the year or a larger midwater trawl may be more effective.

Although midwater trawl abundance estimates of prey are biased, the results are no less useful than similar estimates based on bottom trawl survey methods. In fact, there are several advantages to summer midwater trawling, especially in Canadian waters. First, for the 115 tow midwater survey the 95% confidence limits for smelt and alewives were +/-38 and 49% of the stratified mean, respectively. This is directly comparable to the precision observed in U.S. bottom trawl surveys. However, bottom trawl surveys require a 100+ tows for each species and they cover one-half the area. Another advantage of the midwater survey are estimates of abundance for YOY, which are unavailable from spring, bottom trawl surveys. Furthermore, midwater trawl surveys are not constrained by bottom type; thus allowing prey assessments at locations never before surveyed. For the above reasons, midwater trawling is valuable as a trend-through-time index of smelt or alewife abundance.

Improving Midwater Trawl Survey Technique

Contamination of the trawl catches in the metalimnion and hypolimnion by fish from the strata above the target depth have been considered in previous studies. Schaner et al. (1990) suggested that the level of contamination was similar in magnitude to catches observed in the hypolimnion and metalimnion. Theoretically, this problem should be most extreme where fish abundance in the epilimnion is much larger that the other zones and where it takes a long time to lower or retrieve the net through this zone. The best example of this in our survey is catches of YOY alewife. To assess the magnitude of the contamination problem we will assume that the metalimnion and epilimnion catches of YOY alewife were completely due to contamination. Assuming zero catches in these zones would lead to a 12% lower estimate of YOY alewife abundance after expansion by the volume of the strata. The potential error in the abundance estimates caused by net contamination should be less than 12% for the other species-groups since their peak abundances were in the metalimnion. Enzenhoffer and Hume (1989) described a closeable trawl system which should remove the problem of contamination of catches, and should be considered for future surveys in Lake Ontario.

Schaner et al. (1990) found that catches of both alewife and smelt were highest at 30 m bottom depth and dropped off markedly at 60 and 90 m. Catches were also different between limnological zones. Sampling during the 1990 survey was stratified into six nearshore locations and one offshore location (>79 m bottom depth). Examination of the 1990 data suggests that within the nearshore locations (<80 m bottom depth) catches for all species-groups are lowest in the deepest water. However, differences due to depth were small in comparison to the differences between limnological and location strata. The relationship between bottom depth and catch was not always linear and it was not always consistent between locations and limnological zones. Therefore, without increasing the sampling effort substantially we do not suggest using additional stratification by depth.

Acknowledgments

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Status of Lake Whitefish Populations in Eastern Lake Ontario

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Lake Ontario Fisheries Unit, 1990 Annual Report LOA 91.1 (Chapter 10)

Data from index gillsetting and trawling programs suggest increasing lake whitefish populations with good recruitment. Harvests in the commercial fishery have also increased. Collectively, index gillsetting, trawling, stock discrimination studies and recent surveys of whitefish spawning shoals provide a sound basis for future whitefish management.

Recommendations

1. A whitefish population model should be developed by consolidating index netting, mark-recapture, and commercial fishing harvest data after completion of stock discrimination studies.
2. Reinstate biological sampling of the commercial harvest.
3. Mark whitefish during walleye mark-recapture studies to determine population size of Bay of Quinte stock.
4. Conduct fry emergence trapping and larval whitefish assessment on Bay of Quinte spawning shoals and survey Lake Ontario shoals.

Introduction

Lake whitefish (*Coregonus clupeaformis*) populations of eastern Lake Ontario are composed of two major stocks; one spawning mostly along the south shore of Prince Edward County, the other spawning in the Bay of Quinte. Historically, the Bay of Quinte stock contributed the greatest number of whitefish to the commercial fishery (Christie 1973). A tremendous resurgence of the bay stock has been documented (Bowlby 1990). Gillnet catches indicated that stocks mix freely during the summer months in eastern lake Ontario (Ihssen 1984; Ihssen et al. 1985). However, until stock discrimination techniques are applied to the index netting data, the status of the lake stock will remain unknown. This report updates the status of whitefish populations (mixed stocks) in the Canadian waters of eastern Lake Ontario.

Methods

The focus of this report is on catch data from eastern Lake Ontario assessment gillsets for the years 1986-1990 (Stewart 1991; Mathers 1989; Bowlby and Mathers 1989). The reader is referred to these reports for design and sampling details.

Based on the relationship between the mean and variance of the catches (Taylor's Power Law, Elliot 1979), all data were transformed ($X^{0.25}$) prior to statistical analysis. To analyze changes in abundance among years, a three factor analysis of variance (ANOVA) model was applied with year, station, and depth as factors. A reduced linear ANOVA model was developed iteratively by eliminating all insignificant interactions with a probability level greater than 0.2. It was suspected that some of the difference in catch among depths, areas and years was due to variations in temperature. Therefore, temperature was included as a covariate in the reduced model.

An alternative approach to statistical analysis of these data was also tried. While temperature is a major factor in determining catch of whitefish, a simple index of abundance can be derived by treating the sum of the catches across all depths as a sample. This has the effect of integrating temperature differences among sites and depths in different years. The sum of whitefish catches across all depths comprising a transect were subject to a two factor ANOVA including only year and area as factors (i.e. ignoring depth and temperature).

Data were analyzed in two site groups (Fig. 1); eastern outlet basin (Platt Point, Grape Island, and Melville Shoal, 1986-1990); and central/west Lake Ontario (Brighton, Wellington, and Rocky Point, 1988-1990). Differences between years were examined using least-square means (SAS, LSMEANS procedure) for the covariate analysis

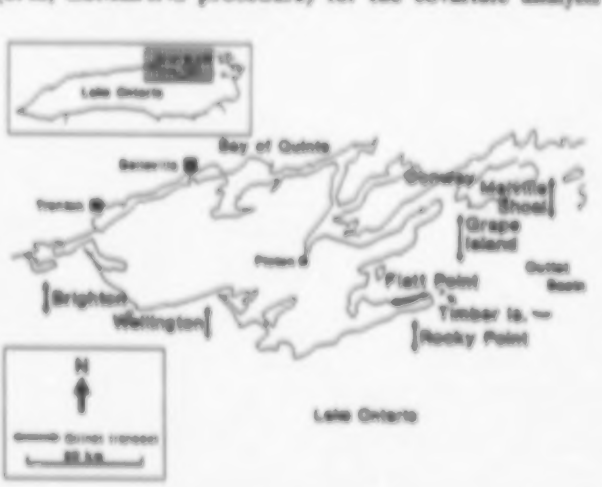

FIG. 1. Location of assessment gillnet transects and research trawling sites.

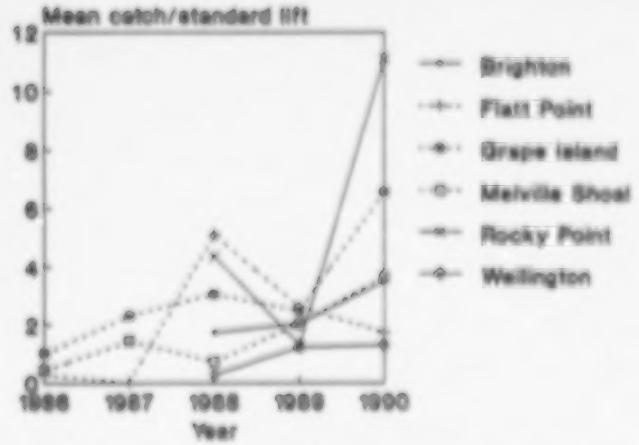

FIG. 2. Catches of lake whitefish in index assessment gill nets in Lake Ontario.

TABLE 1. Summary of differences in catches among years based on treating each depth as a sample and including temperature as a covariate in the model. Differences were tested ($p = 0.05$) using the LSMEANS procedure which does not control for experimentwise error rate. Years are ranked according to the value of the mean (lowest to highest) and means with the same letter are not significantly different.

Site Group	Rank of means				
Outlet basin	86	87	89	88	90
			A	A	A
	B	B	B		
Central/west			88	89	90
			A	A	A

and Student-Newman-Keuls multiple range test (Sokal and Rohlf 1981) for the transect model. Graphical trends only, were considered for the Research series gillnetting (Casselman et al. 1991), bottom trawling (Hurley 1991), and commercial harvest reports to augment these analyses.

Results and Discussion

Catches varied considerably among sites with some indication of an increasing trend (Fig. 2). For the eastern outlet basin sites, whitefish populations were significantly higher in 1989 and 1990 compared to 1986 and 1987 (Table 1). For central/west Lake Ontario there was no difference among years (Table 1). The alternative analysis, using the catches summed over all depths as a sample, produced the same conclusions (Table 2). Both approaches failed to conclude that the large increase in mean catches from 1989 to 1990 (Fig. 3) were statistically significant. This illustrates the high variability in these data, and emphasizes that these programs should be considered only as low resolution indices of population abundance.

TABLE 2. Summary of differences in catches among years based on catches summed over depth. Differences were tested at $p = 0.05$ using the Student-Newman-Keuls procedure controlling for experimentwise error. Years are ranked according to the value of the mean (lowest to highest) and means with the same letter are not significantly different.

Site Group	Rank of means				
Kingston	86	87	89	88	90
			A	A	A
	B	B			
Central/west			88	89	90
			A	A	A

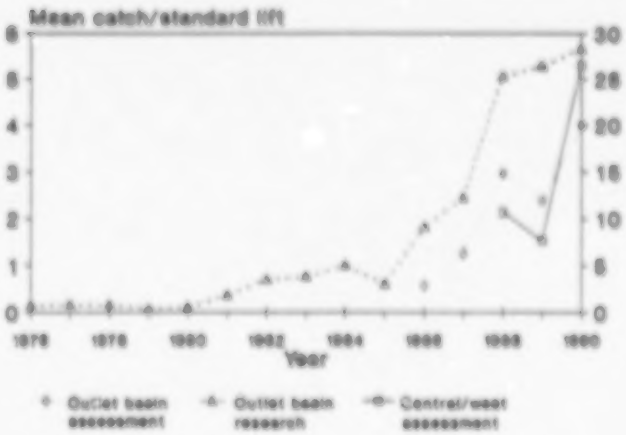

FIG. 3. Mean catches of of lake whitefish in assessment and research gillnets. outlet basin research catches represent the mean from six sites in the outlet basin. Outlet basin assessment catches correspond to the mean of catches at the Flatt Point, Grape Island, and Melville Shoal transects, while central/west basin assessment catches correspond to the mean of the Brighton, Wellington, and Rocky Point transects.

These results complement general trends in the eastern outlet basin Research Gillnet Program which suggest a steady increase in whitefish populations since 1985 (Fig. 3). Bottom trawling results suggest continued reproductive success. The Conway site is likely capturing only Bay of Quinte stock whitefish while the stock composition of Timber Island trawling site is unknown. However, good catches of young-of-the-year whitefish at both sites since 1986, confirm continued successful spawning and early survival (Fig. 4).

Commercial fishing harvests have also increased (Fig. 5). In 1990, most fishermen reached their quotas for the first time in many years (Dave Montgomery, Napanee District, O.M.N.R., pers. comm.).

All these results point to a sustained recovery of lake whitefish in eastern Lake Ontario. Similar increases in catches of lake herring (*Coregonus artedii*) in recent years (Stewart 1991) suggest that these congeners are responding positively to similar environmental or fish community changes. Predation by smelt (*Osmerus mordax*) has been im-

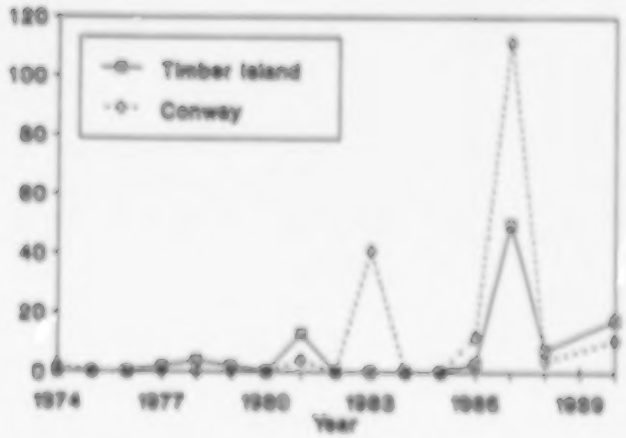

FIG. 4. Catch-per-unit-of-effort (fish/ 12 min tow) of YOY lake whitefish (fork length 113 mm) at Conway and Timber Island.

FIG. 5. Commercial harvest of lake whitefish in the Napanee District of Lake Ontario.

plicated in recruitment failure of both whitefish and lake herring (Loftus and Hulsman 1986; Christie 1973) and the abundance of large smelt has declined in Lake Ontario (Casselman et al. 1991; Mathers and Stewart 1990; O'Gorman et al. 1989). It is possible that the recent recovery of whitefish populations in eastern Lake Ontario is due to a reduction in predation by smelt on larval whitefish.

Index gillnetting and trawling programs have the potential to provide a sound basis for whitefish management but are hampered by our inability to distinguish stocks. Work to discriminate Lake Ontario and Bay of Quinte stocks based on scale and otolith characteristics is progressing well (John Casselman, Lake Ontario Fisheries Unit, O.M.N.R., pers. comm.) and will be applied to the index netting data presented here. Biological sampling of the commercial harvest must be reinstated to establish the age composition of the harvest. Marking of whitefish during walleye mark-recapture studies is a cost-effective way of obtaining population estimates for the Bay of Quinte stock (Bowlby 1990) and should be continued. As well, better understanding of whitefish recruitment, and in particular the effect of zebra mussel (*Dreissena polymorpha*) invasion, can be enhanced with follow-up work concentrating on surveyed spawning shoals in the Bay of Quinte (Hoyle and Melkic 1991).

Acknowledgments

I thank the Operations staff at LOFU for collecting the data from various programs and the Systems staff for timely data entry and verification. Thanks to Dave Montgomery for providing commercial harvest statistics. Jim Hoyle, Jim Bowlby, Steve Kerr and Phil Smith commented on a previous draft. Carol Ward for copy editing and Linda Balsillie transformed this text into Ventura format.

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Preliminary Report on the Salmonid Fishery in Western Lake Ontario

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Preliminary results for the western Lake Ontario salmonid fishery were presented for launch ramps where anglers were surveyed in Maple district during summer. In 1990, catch, harvest, catch-per-unit-effort (CUE), harvest-per-unit-effort (HUE), and effort of the salmonid fishery declined at Port Credit and Bluffer's Park ramps during July and August. Effort declines were likely related to poor weather in 1990. Overall declines in catch, harvest, CUE, and HUE were driven by declines in catch and harvest of chinook salmon. In turn, declines in CUE and HUE of chinook may be related to changes in stocking numbers and locations.

Introduction

Angler catch and effort in the salmonid fishery in western Lake Ontario (Salmon Point to Niagara River) was relatively stable from 1986 to 1989 (Stewart et al. 1990). This is a preliminary report on the fishery in 1990.

Methods

Field work was contracted to an independent consultant. The design generally followed past access point surveys of launch ramps (Daniels and Savoie 1986; Stewart et al. 1990), but was modified as described below. Detailed methods were reported by Savoie (1990).

Anglers that launched their boats at selected ramps (Table 1) in western Lake Ontario were surveyed for catch, harvest, and effort information during April to September 1990. Each ramp was surveyed on two weekdays and two weekend days each month.

Additional effort data was collected by counting the number of parked boat trailers at all ramps that were used by salmonid anglers in western Lake Ontario (Table 2). Counts were made on one weekday and one weekend day each week during April to September between 1000 and 1500 hr. Some trailer count data from April and May, and some angler survey data from September were not used because routine audits invalidated these data.

Analyses were stratified on the basis of weekday vs. weekend, launch ramp, and month. These analyses are ongoing at the time of writing, and so preliminary results are presented here to provide insights into changes in the characteristic of the salmonid fishery in western Lake Ontario.

Results and Discussion

The preliminary results for the western Lake Ontario salmonid fishery were for the Port Credit and Bluffer's Park ramps in Maple District, during July and August. In 1989, these months and sites accounted for 13% of the catch, harvest, and effort of "launch daily anglers" (calculated from Stewart et al. 1990). During this period, these sites reflect the general trend of the entire fishery (Stewart et al. 1990).

In 1990, catch, harvest, and effort of the salmonid fishery declined in Maple District during July and August (Fig. 1). The catch and harvest declined at a greater rate than effort as indicated by CUE and HUE (Fig. 2). Effort declines were likely related to poor weather in 1990. CUE and HUE declines were driven by declines in catch and harvest of chinook salmon (Fig. 3, 4, 5, and 6). Ontario stocked fewer chinook in 1987-1989 than 1984-1986 (LeTondre and Savoie 1990), and this may account for those declines. Furthermore, since 1987, fewer chinook have

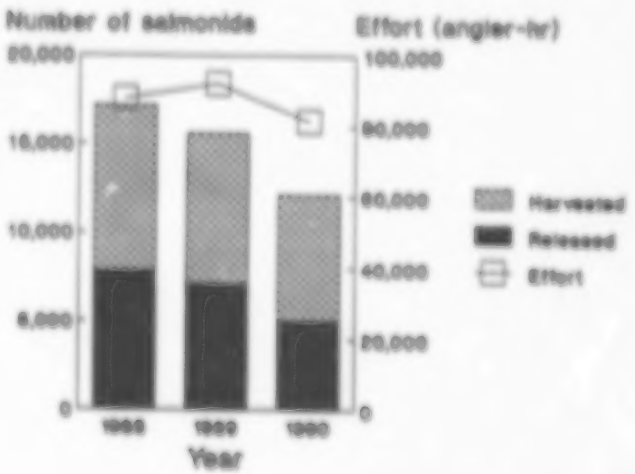

FIG. 1. Total catch, harvest and effort of salmonid anglers at Bluffer's Park and Port Credit launch ramps during July and August, 1988-1990. Catch equals harvested plus released.

TABLE 1. The survey month for each launch ramp surveyed on western Lake Ontario during 1990.

Launch ramp	District	April	May	June	July	August	Sept.
St. Catharines Game and Fish Assoc.	Niagara	X	X	X	X	X	X
Fifty Mile Point Conservation Area	Cambridge	X	X	X	X	X	X
Bronte Beach Park	Cambridge			X	X	X	X[1]
Port Credit Ramp	Maple	X	X	X	X	X	
Bluffer's Park (MTRCA)	Maple			X	X	X	X
Whitby Government Ramp	Lindsay	X	X	X	X	X	X
Port Darlington Ramp (CLOACA)	Lindsay			X	X	X	X[2]
Ontario Street Ramp (Brighton)	Napanee			X	X	X	X[1]

[1] sampled twice
[2] sampled once

TABLE 2. Launch ramps where trailers were counted on western Lake Ontario during 1990.

Launch ramp	District
Queenston sand docks	Niagara
Niagara-on-the-Lake (Old Boat Works)	Niagara
St. Catharines Game and Fish Assoc.	Niagara
R.W. Marine (Port Dalhousie)	Niagara
Beacon Motor Inn (Jordan Harbour)	Niagara
Campbell's Boats (Jordan Harbour)	Niagara
Grimsby Municipal Ramp	Niagara
Foran's Marine (Grimsby)	Niagara
Lakecourt Marine (Grimsby)	Niagara
Fifty Mile Point Conservation Area	Cambridge
Fisherman' Wharf (Hamilton)	Cambridge
Mohawk Canoe Club (Burlington)	Cambridge
Bronte Beach Park	Cambridge
Coronation Park (Oakville)	Cambridge
Shipyard Park (Oakville)	Cambridge
Bisley Park (Oakville)	Cambridge
Port Credit Ramp	Maple
Lake Promenade Park (Lakeview)	Maple
Marie Curtis Park (MTRCA)	Maple
Humber Bay West (MTRCA)	Maple
Ashbridges Bay (MTRCA)	Maple
Bluffer's Park (MTRCA)	Maple
Frenchman's Bay East (Pickering)	Maple
Port Whitby Marina	Lindsay
Whitby Government Ramp	Lindsay
Port Oshawa Marina	Lindsay
Port Darlington Ramp (CLOACA)	Lindsay
Port Hope Marina	Lindsay
Cobourg Yacht Club	Lindsay
Ontario Street Ramp (Brighton)	Napanee
Brighton Marina	Napanee
Gosport Government Ramp	Napanee
Wellington Beach Ramp	Napanee
Wellington Government Ramp	Napanee

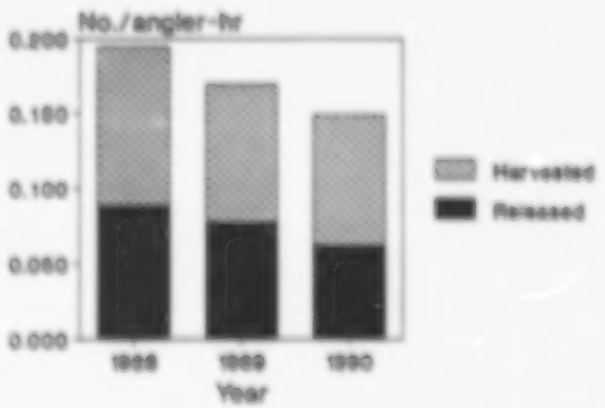

FIG. 2. CUE and HUE of salmonid anglers at Bluffer's Park and Port Credit launch ramps during July and August, 1988-1990. Catch equals harvested plus released.

been stocked in Maple District to provide chinook for stocking Lindsay and Napanee Districts.

The catch was dominated by chinook, followed by rainbow trout and coho salmon, respectively (Fig. 3). The harvest and HUE of coho increased in 1990 (Fig. 4 and 6), despite declining catch (Fig. 3). Anglers may have kept more coho in 1990 because of lower chinook catches or perhaps as a response to decreasing contaminants. In 1989, coho less than 45 cm from the Credit River were considered safe from contaminants for unrestricted consumption (Anonymous 1989), but, in 1990, coho less than 55 cm from the Credit River were considered safe for unrestricted consumption (Anonymous 1990). Rainbow catch statistics for 1990 were similar to 1989.

In 1989, Ontario fell short of stocking targets for Lake Ontario by 190,000 fish (LeTendre and Savoie 1990). Overall catch in the salmonid fishery might be increased by reaching the proposed stocking targets, or by improving habitat and wild salmonid production to compensate for lower stocking levels.

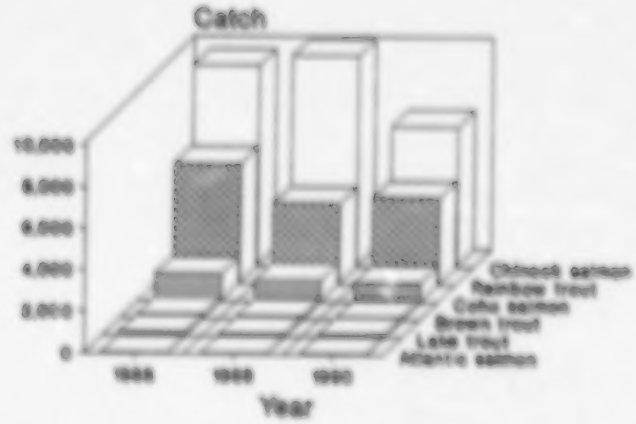

FIG. 3. Species-specific catch of salmonid anglers at Bluffer's Park and Port Credit launch ramps during July and August, 1988-1990.

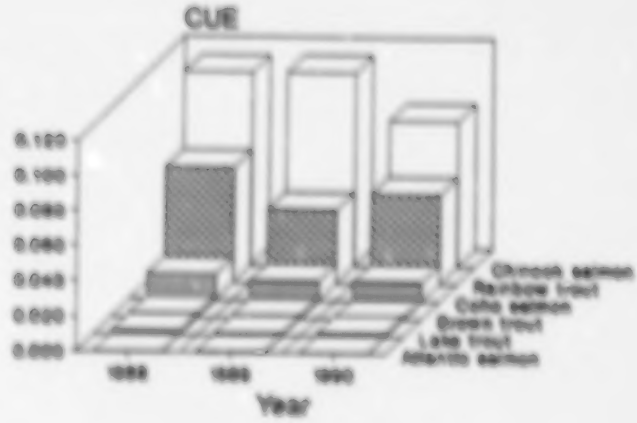

FIG. 5. Species-specific CUE of salmonid anglers at Bluffer's Park and Port Credit launch ramps during July and August, 1988-1990.

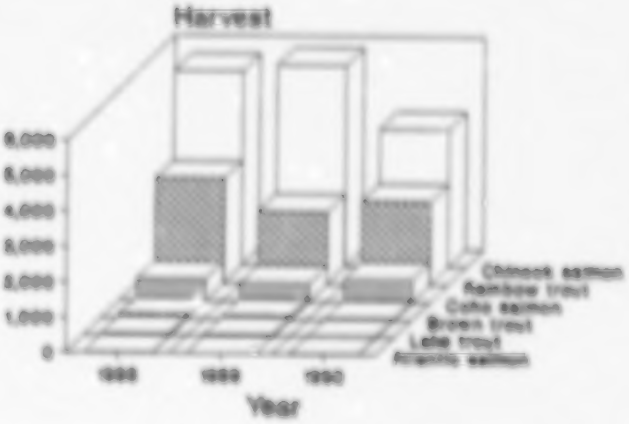

FIG. 4. Species-specific harvest of salmonid anglers at Bluffer's Park and Port Credit launch ramps during July and August, 1988-1990.

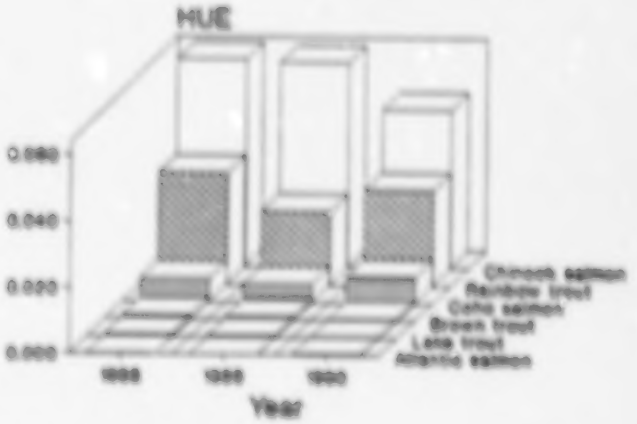

FIG. 6. Species-specific HUE of salmonid anglers at Bluffer's Park and Port Credit launch ramps during July and August, 1988-1990.

Acknowledgments

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Trends in Nutrient and Biological Variables in the Off-Shore: A Preliminary Report of the Lake Ontario Biomonitoring Program

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The Lake Ontario Biomonitoring Program has collected information from two off-shore stations, one in the main lake and the other in the eastern basin, on a weekly basis from April to October since 1981. For the present analyses, we delineated two periods within the season - prestratified and stratified - and analyzed nutrient and biological variables for trends through the 1981-1989 period. Total phosphorus and total filtered phosphorus declined at both stations while nitrate-nitrite increased. In the shallow eastern basin, corresponding declines occurred in algal biomass, particularly diatoms and dinoflagellates, and during the stratified period, in particulate organic nitrogen. No corresponding declines in algal biomass were observed in the main lake; however, during the stratified period, particulate organic carbon and nitrogen, and chlorophyll *a* decreased.

Background

The Lake Ontario Biomonitoring Program commenced in 1981. The project was designed, in part, to assess the state or "health" of the ecosystem by following trends in nutrient chemistry, physical conditions and the sub-vertebrate biological community. Because biological variables change rapidly through the season, and because development of the biological community is similar throughout much of the open-waters of the lake (e.g. Patalas 1969; Johannsson and Minns 1987), the program samples a minimum number of stations, frequently. Two stations, one in the centre of the lake 28 km south of Chub Point at 130 m depth (station 41), and one in the central plain of the eastern basin at 34 m depth (station 81), are sampled weekly from the beginning of April until the end of October.

To date, under the auspices of this program, the phytoplankton, zooplankton and benthos communities of the early 1980's have been compared with those described in earlier years (Johannsson et al. 1985; Johannsson 1987). Changes in the zooplankton community during the 1980's have been analyzed (Johannsson et al. 1991); ciliate and rotifer production have been estimated (Taylor and Johannsson 1991); and interactions between zooplankton and alewife have been examined (Johannsson and O'Gorman 1991). Sufficient information now exists to examine trends in nutrient and biological variables through the 1980's. The analyses of these data are in progress: the following is a preliminary report of results to date. With the continuing reduction in phosphorus loading to the lake, and the high levels of salmonid stocking, changes in nutrient levels and abundance of biota would be expected. Trends in these variables should assist in the assessment of management strategies.

Methods

The methods used in the Lake Ontario Biomonitoring Program are described in detail in Johannsson et al. (1985). Briefly, a temperature profile was obtained with an electronic bathythermograph. Density was calculated at 0.5 m intervals and the mixing depth (or top of the thermocline) was taken as the depth of the maximum density gradient. A criterion of 0.08 $kg.m^{-3}.m^{-1}$ was chosen as the minimum density gradient required to delineate a mixed depth. At 10°C , this criterion is met with a thermal gradient of 0.8 to $0.9°C.m^{-1}$, while at 20°C, $0.4°C.m^{-1}$ was sufficient. We collected an integrated water sample from the surface to 1 m above the thermocline, or to 20 m if the thermocline was deeper or the lake unstratified. From this sample, water was taken for all measures except zooplankton and oxygen; that is, particulate organic carbon (POC) and nitrogen (PON), chlorophyll*a*, total phosphorus (TP), total filtered phosphorus (TFP), soluble reactive phosphorus (SRP), nitrate-nitrite (NO_3NO_2), total Kjeldahl nitrogen (TKJN), ammonia (NH3), chloride (CL), soluble reactive silica (SRS), pH and conductivity (COND). Oxygen was measured in a discrete sample taken from the mid-depth of the mixed layer.

Zooplankton were collected with a 64 u-mesh, 50 cm-diameter net hauled vertically through the same depth as the integrated sample.

From 1982 until 1984, phytoplankton was collected on Millipore filters and chlorophyll *a* extracted with 90% acetone. However, in Lake Ontario, the Millipore and GF/C (with 90% acetone extraction and grinding) techniques did not produce significantly different estimates of chlorophyll *a*. In 1985, we reverted to the GF/C procedure which is used extensively in associated programs.

In the present analyses, the data were divided into three groups, seasonal (April to October), prestratified and stratified. The prestratified period extended from the beginning of April until the mixed depth was less than 20 m. The stratified period commenced 18 d after the onset of stratification and ended when the mixed depth exceeded 20 m. The data were expressed as annual means, within each group, and compared across years. In order to evaluate the significance of increasing or decreasing trends, we applied a directional Sign Test. In this test, the direction of change between each mean and that of each subsequent year are tallied and the probability of the tally calculated (Siegel 1956). When a trend was significant, the data were plotted to establish whether the trend was meaningful or merely a consistent change within a subset of years.

Results

Eastern Basin

Nutrient conditions changed significantly between 1981 and 1989; TP and TFP decreased while NO_3NO_2 increased (Fig. 1). During the prestratified period, TP fell from approximately 0.0130 $mg.L^{-1}$ to 0.0100 $mg.L^{-1}$ ($p<0.001$), and TFP, from 0.0055 $mg.L^{-1}$ to 0.0047 $mg.L^{-1}$ ($p=0.001$). Most of this change occurred in one step between 1984 and 1985. Nitrate-nitrite increased between 1981 and 1984 from 0.250 $mg.L^{-1}$ to 0.300 $mg.L^{-1}$ and then stabilized ($p=0.04$). The changes were more pronounced during the stratified period, and the step down occurred a year later between 1985 and 1986. Total phosphorus decreased from approximately 0.0160 $mg.L^{-1}$ to 0.0105 $mg.L^{-1}$ ($p=0.002$); and TFP declined from 0.0080 $mg.L^{-1}$ to 0.0052 $mg.L^{-1}$ ($p=0.002$). Nitrate-nitrite rose erratically from 0.100 $mg.L^{-1}$ to 0.138 $mg.L^{-1}$ ($p=0.005$).

Over the season (April to October) significant declines occurred in POC ($p=0.002$), PON ($p<0.001$), and total algal biomass ($p<0.001$). Chlorophyll *a* also decreased, but the trend was not significant ($p=0.072$). Both dinoflagellates ($p<0.001$) and cryptophytes ($p=0.014$) contributed to the decline in total algal biomass. In conjunction with these changes, Secchi depth increased approximately 2 m. Most of the changes in biological variables were restricted to the stratified period. Only total algal biomass declined in the prestratified period, due principally to decreases in diatoms in 1983 and 1986-1988 ($p=0.004$) and in dinoflagellates in 1985 and 1987-1988 ($p=0.004$) (Fig. 2). Secchi depth also increased significantly at this time ($p=0.042$). During the stratified period, PON ($p<0.001$) and total algal biomass ($p=0.001$), principally dinoflagellates ($p=0.001$), declined (Fig. 3). The changes were not sufficient to alter the Secchi depth. Declines in POC and chlorophyll *a* were not significant ($p=0.072$).

Main Lake

Nutrient concentrations changed in a similar fashion in the main lake as in the eastern basin (Fig. 4). Total phosphorus ($p<0.001$) and TFP ($p<0.001$) declined in all periods of the year. Increases in NO_3NO_2 were observed for the whole season ($p=0.001$) and stratified period ($p<0.001$), but not for the prestratified period. During the prestratified period, TP declined from 0.0133 $mg.L^{-1}$ to 0.0102 $mg.L^{-1}$ ($p<0.001$); and TFP, from 0.0090 $mg.L^{-1}$ to 0.0050 $mg.L^{-1}$ ($p=0.005$). Most of the drop occurred between 1986 and 1987, a year later than in the eastern basin. Unlike the situation in the eastern basin, SRP also decreased from 0.0037 $mg.L^{-1}$ to 0.0012 $mg.L^{-1}$ during the prestratified period ($p<0.001$). During the stratified period, TP declined from 0.0150 $mg.L^{-1}$ to 0.0101 $mg.L^{-1}$ ($p<0.001$); and TFP, from 0.0072 $mg.L^{-1}$ to 0.0043 $mg.L^{-1}$ ($p<0.001$). Again, TP dropped between 1986 and 1987 while TFP declined gradually. Nitrate-nitrite rose from 0.060 $mg.L^{-1}$ to 0.180 $mg.L^{-1}$ ($p<0.001$).

Biological changes occurred predominantly during the stratified period (Fig. 5). Particulate organic carbon ($p<0.001$) and PON ($p=0.001$) decreased by 40% and chlorophyll *a* ($p=0.05$) by 14%, while Secchi depth increased from 3.7 m in 1981-1985 to 4.6 m in 1987-1988 and 6.1 m in 1989. Total algal biomass did not change significantly, although low values were observed in 1981, 1987 and 1988. Data are not yet available for 1989. Like the trends in TP and TFP, the biological variables changed most between 1986 and 1987.

On the other hand, no significant trends occurred in chlorophyll *a*, Secchi depth or total algal biomass during the prestratified or seasonal periods. During the prestratified period, low seston biomasses were observed from 1982 until 1984 (Fig. 6), and were responsible for significant trends in POC ($p=0.042$) and PON ($p=0.030$). A similar pattern was observed in chlorophyll *a*. Total algal biomass was also particularly low in 1984, and chrysophycaean biomass, in 1983. The only significant trend during this period was an increase in chrysophytes from 0.047 $mg.m^{-3}$ to 0.071 $mg.m^{-3}$, principally between 1985 and 1986 ($p=0.014$). When the season was examined as a whole, only PON showed a significant decline ($p<0.001$), and within the algae, chrysophytes increased from approximately 0.010 $mg.m^{-3}$ to 0.225 $mg.m^{-3}$ ($p=0.037$).

Discussion

The season was divided into two segments for these analyses because different variables control phytoplankton dynamics in the spring when the water column is thoroughly mixed, and in the summer when the lake is stratified. The period immediately following stratification is a time of transition (Reynolds 1984) and was omitted. During this period, the phytoplankton community switches from a more light-limited to a more nutrient-limited state. With the much shorter mixed depth, heavier particles, such as diatoms, tend to fall out of the epilimnion, and mean mixed-depth irradiance increases. Nutrient supplies are reduced with the isolation of the surface waters from the

bulk of the water column, and phosphorus rapidly becomes limiting (Lean et al. 1987).

In the spring before stratification sets up, phytoplankton growth will be controlled first by its light environment and secondarily by nutrient supplies. In deeper regions, such as station 41 in the main lake, the average light level of the deeply mixed waters is low and growth is slow; stratification occurs before nutrient limitation sets in. As bottom depth and mixed depth decreases, the light regime improves and phytoplankton growth rate increases. In shallower regions, such as the eastern basin, nutrient levels become limiting before stratification occurs. Hence, we see different responses to reduced phosphorus concentrations in the two regions. In the deep regions of the main lake, SRP levels declined but no associated decreases occurred in the biological community because it was limited by light, not nutrients. Further, the low levels of POC, PON, chlorophyll *a*, and to a lesser extent, total algal biomass, observed between 1982 and 1984, suggest that cloud cover may have been greater in those years. In the shallower eastern basin, SRP and SRS concentrations had always been driven to limiting levels before stratification developed. As phosphorus levels decreased total algal biomass decreased, particularly the diatoms and dinoflagellates which are normally abundant in the spring. With the decrease in algal biomass, the Secchi depth increased. There was a lack of corresponding decreases in POC and PON. Although algal biomass constitutes only a small portion of total particulate organic carbon or nitrogen, it should drive the system by setting the rate of primary productivity. The lack of a response could be explained if POC and PON were composed mainly of resuspended or imported materials and/or of micro- and macrozooplankton, whose growth is limited by some factor other than total algal biomass, i.e. temperature or more specific algae food sources, such as cryptophytes or chrysophytes, which did not decrease.

Under stratified conditions, phosphorus is rapidly driven to limiting levels. Declines in the phosphorus supply would be expected to cause reductions in algal biomass. In the eastern basin, total algal biomass did decline with diminishing phosphorus concentrations. A significant decrease was also observed in PON. Particulate organic carbon and chlorophyll *a* declined, though the trends were not significant. Zooplankton abundance also decline (Johannsson et al. 1991). Again, the response in the midlake was different from that in the eastern basin. In the midlake, decreases in POC, PON, and to a lesser extent chlorophyll *a*, accompanied the declines in phosphorus, but total algal biomass did not. Zooplankton abundance also declined (Johannsson et al. 1991). Larger individuals of the dominant cladoceran species can drive down the abundance of cryptophytes, chlorophytes and chrysophytes (Johannsson and O'Gorman 1991). It is possible that reduced grazing pressure, particularly in the latter years, has enabled the phytoplankton to maintain their biomass, or that grazing pressure has been variable masking a response in the phytoplankton. A response in the phytoplankton could also be masked if the phosphorus pool for the stratified period was partly determined by phosphorus uptake during the spring. The greater the uptake and removal of phosphorus during spring growth, the smaller would be the input to the phosphorus pool for the summer period. The relative importance of spring uptake is not known. A diminished phosphorus supply could also be compensated for by decreases in phosphorus recycling time.

Both in the midlake and in the eastern basin, the decrease in phosphorus was not linear but stepped. Marked declines occurred between 1984-1985 in the prestratified period and between 1985-1986 in the stratified period in the eastern basin. In midlake the step down took place one year later - between 1986 and 1987. In all three cases, the biological variables also step changed either at the same time or within a year. This close association between the changes in phosphorus and the changes in the biological variables suggests a strong "bottom up" control of the lower portion of the food web by phosphorus. Such control, even in a planktivore-dominated system such as Lake Ontario, is to be expected (McQueen et al. 1986).

The reductions in phosphorus loads to the lake appear to have been effective at reducing algal biomass in the shallower regions throughout the season with accompanying decreases in abundance at higher trophic levels. In the midlake, reductions at higher trophic levels occurred only during the stratified period; algal biomass did not decrease. Obviously, trophic interactions during the stratified period require further study.

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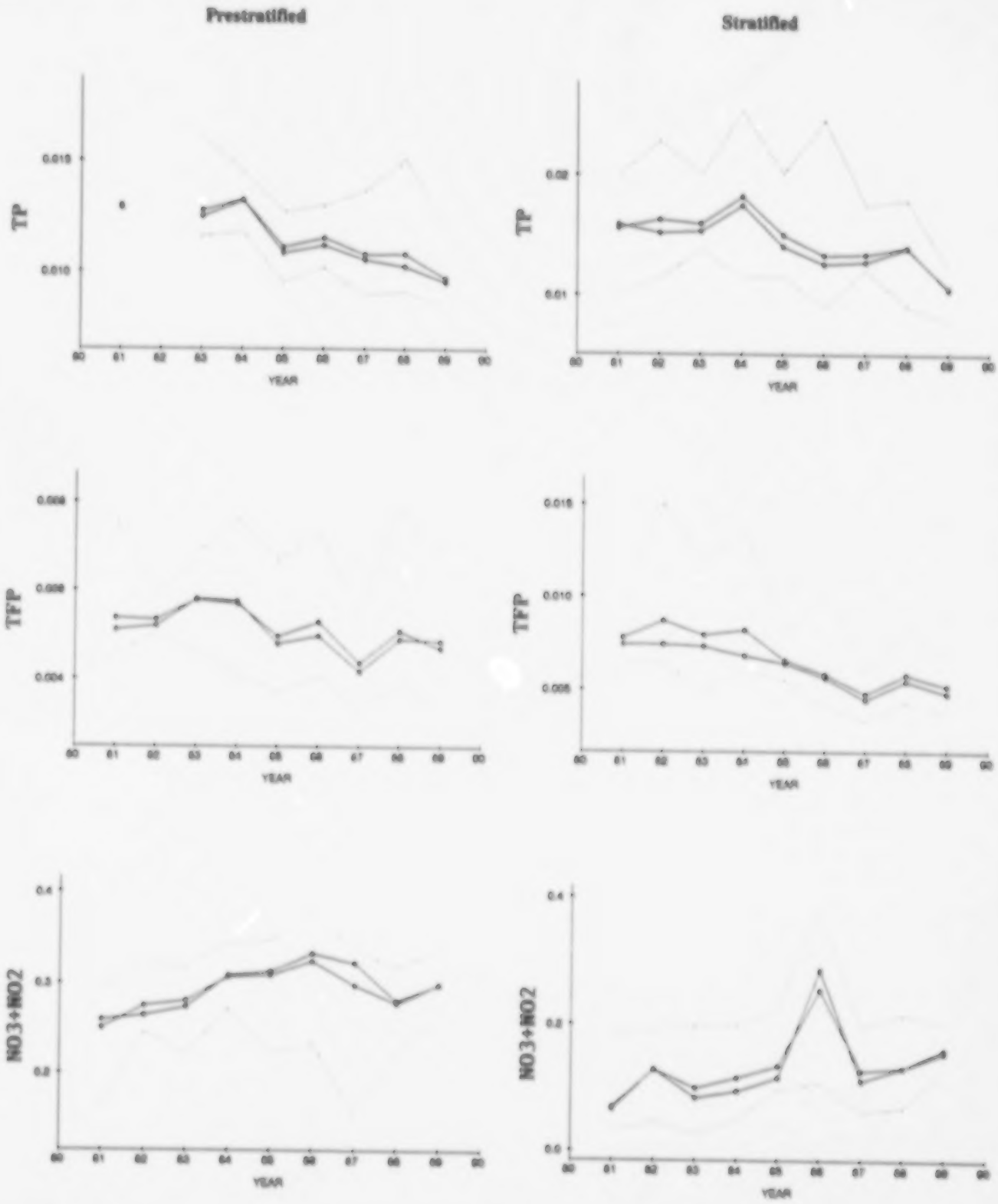

FIG. 1. Nutrient concentrations ($mg.L^{-1}$) during the prestratified and stratified periods are presented for station 81 in the eastern basin (mean (•), median (o), maximum and minimum (–)).

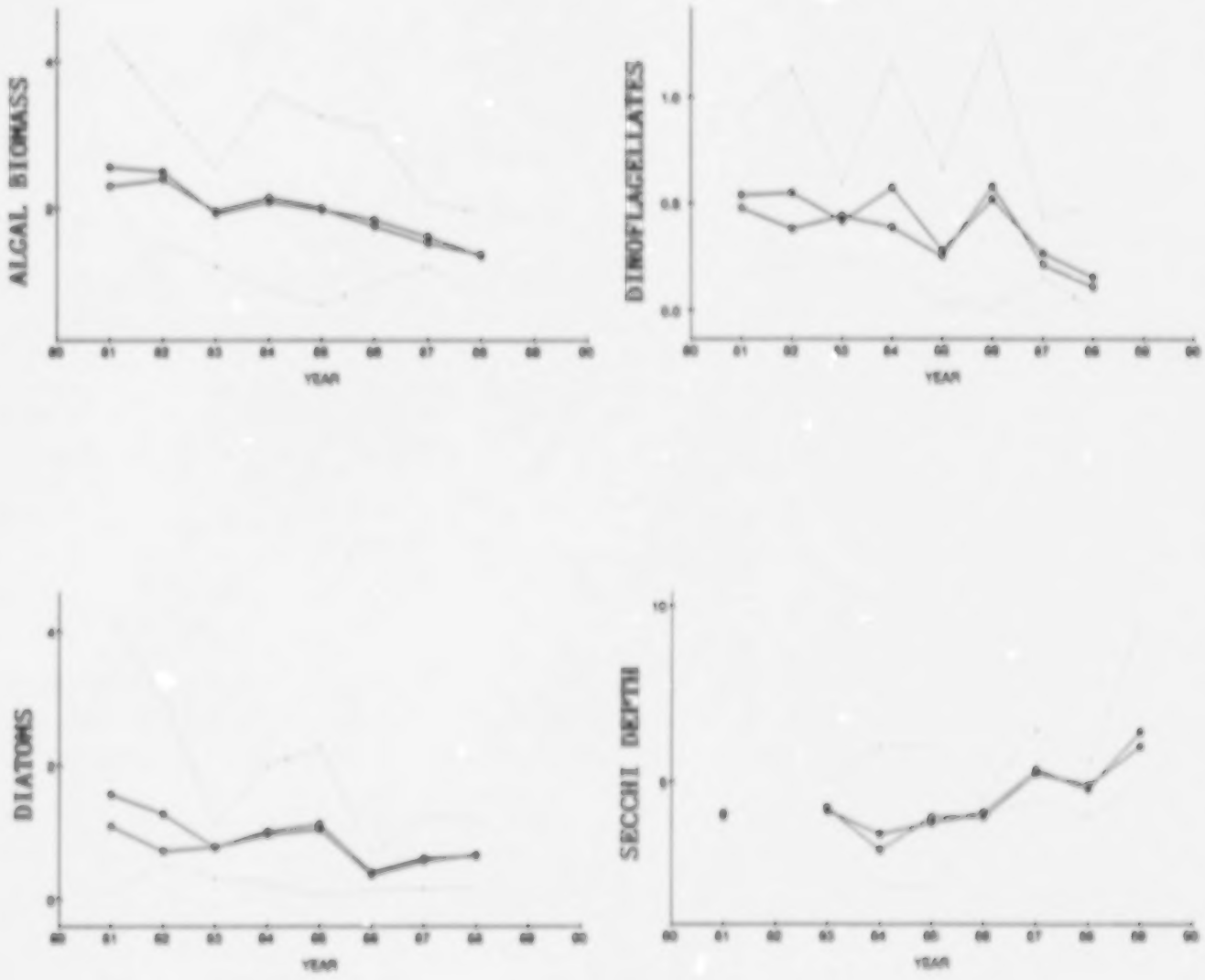

FIG. 2. The biomasses of algae, diatoms and dinoflagellates ($mg.m^{-3}$) and the Secchi depth (m) are presented for the prestratified period for station 81 in the eastern basin (mean (●), median (○), maximum and minimum (–)).

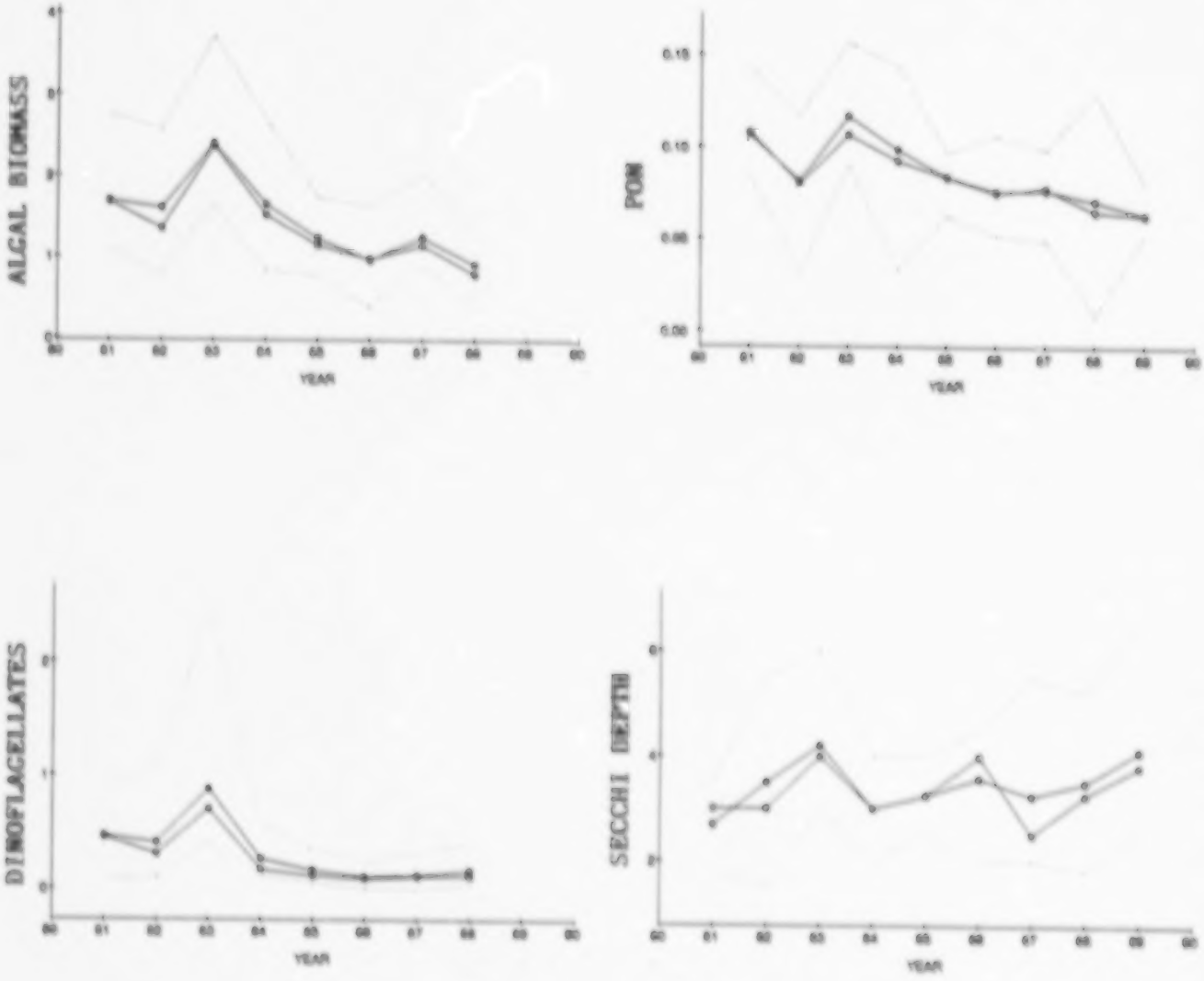

FIG. 3. The biomasses of algae and dinoflagellates ($mg.m^{-3}$), the concentration of particulate organic nitrogen (PON) ($mg.L^{-1}$), and the Secchi depth (m) are presented for the stratified period for station 81 in the eastern basin (mean (•), median (o), maximum and minimum (–)).

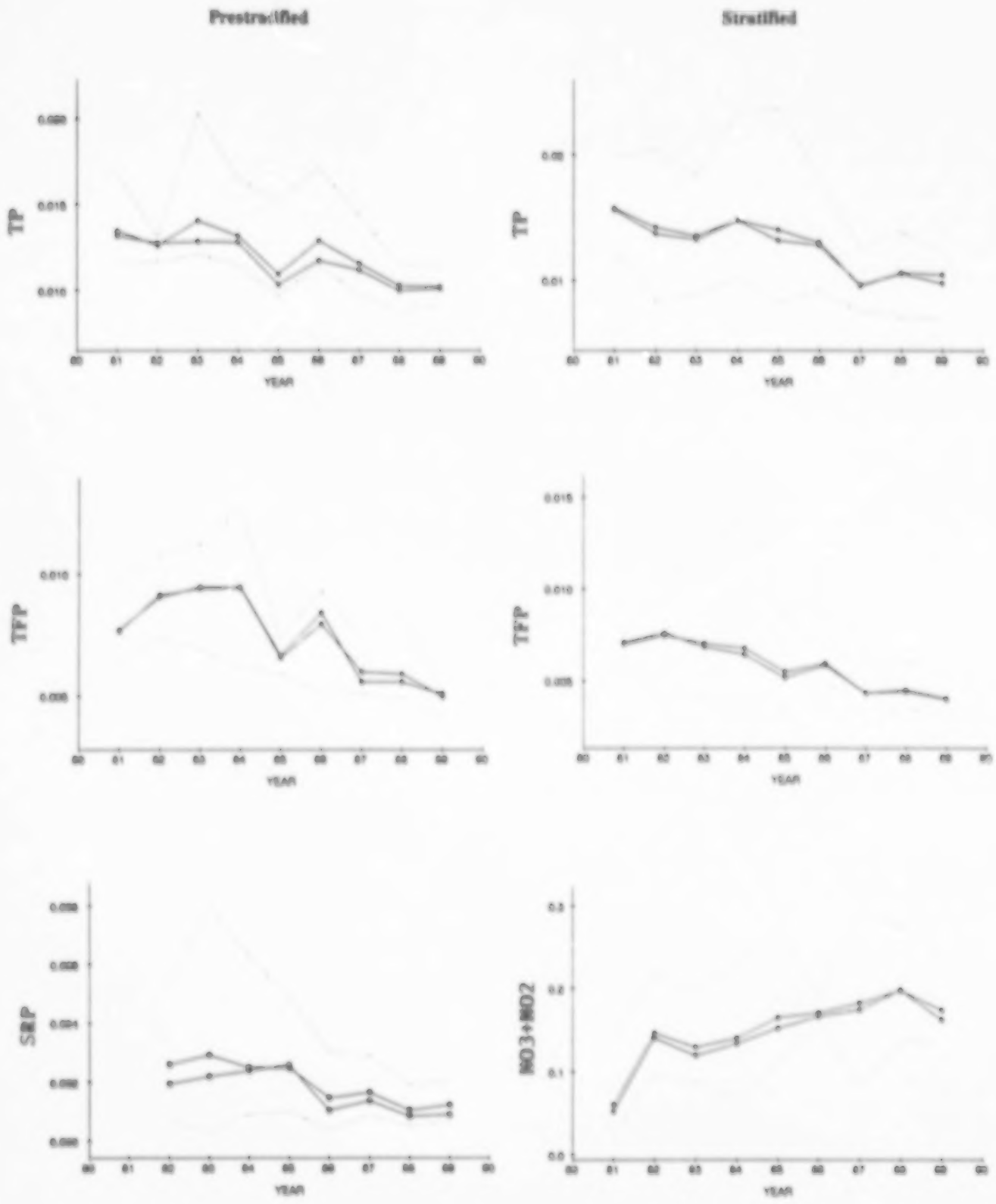

FIG. 4. Nutrient concentrations (mg.L^{-1}) during the prestratified and stratified periods are presented for station 41 in the main lake (mean ⊕), median (○), maximum and minimum (—)).

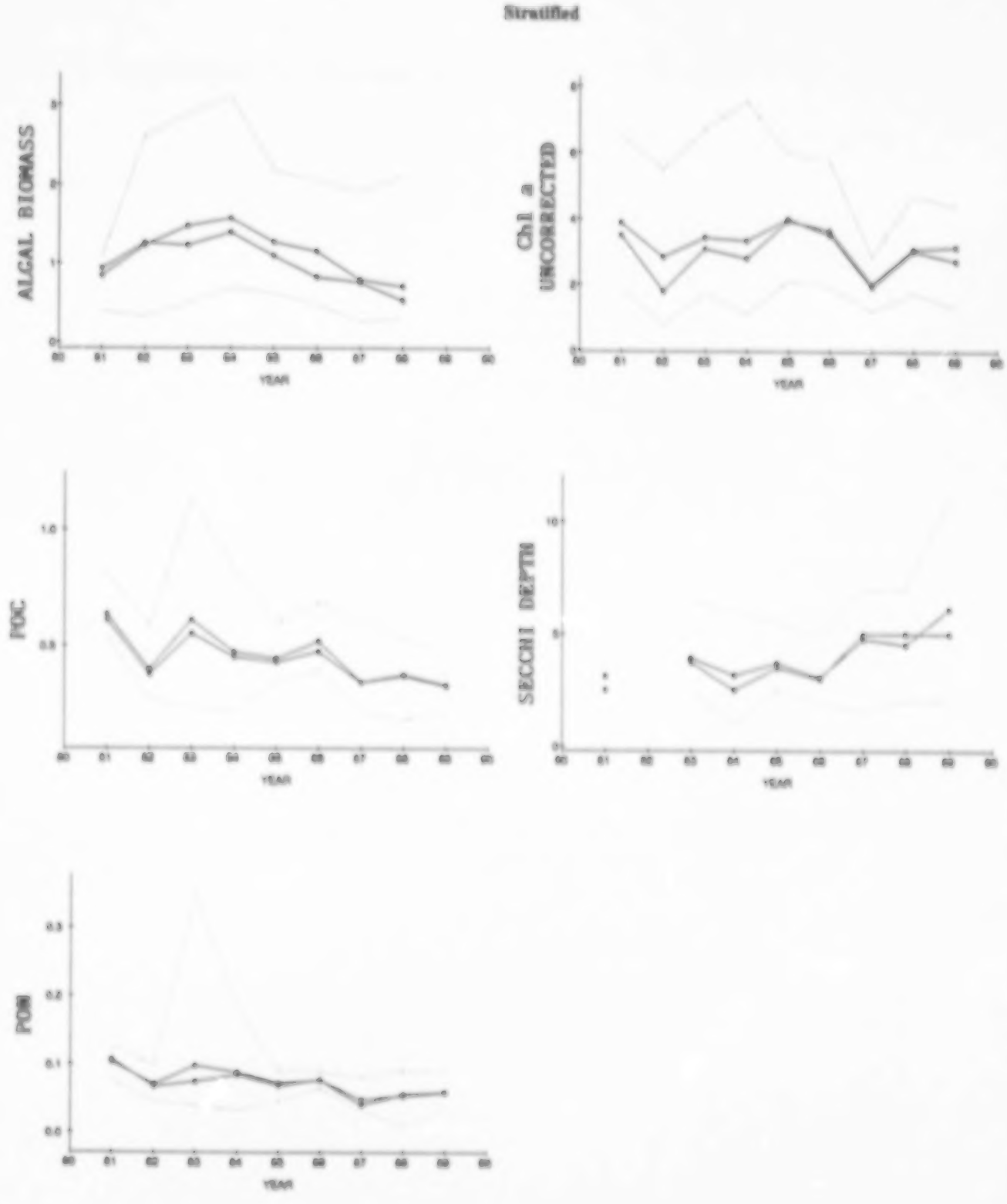

FIG. 5. The biomass of algae ($mg.m^{-3}$), the concentrations of particulate organic carbon (POC) and nitrogen (PON) ($mg.L^{-1}$), and chlorophyll a (Chl a) ($ug.L^{-1}$), and the Secchi depth (m) are presented for the stratified period for station 41 in the main lake (mean (•), median (○), maximum and minimum (–)).

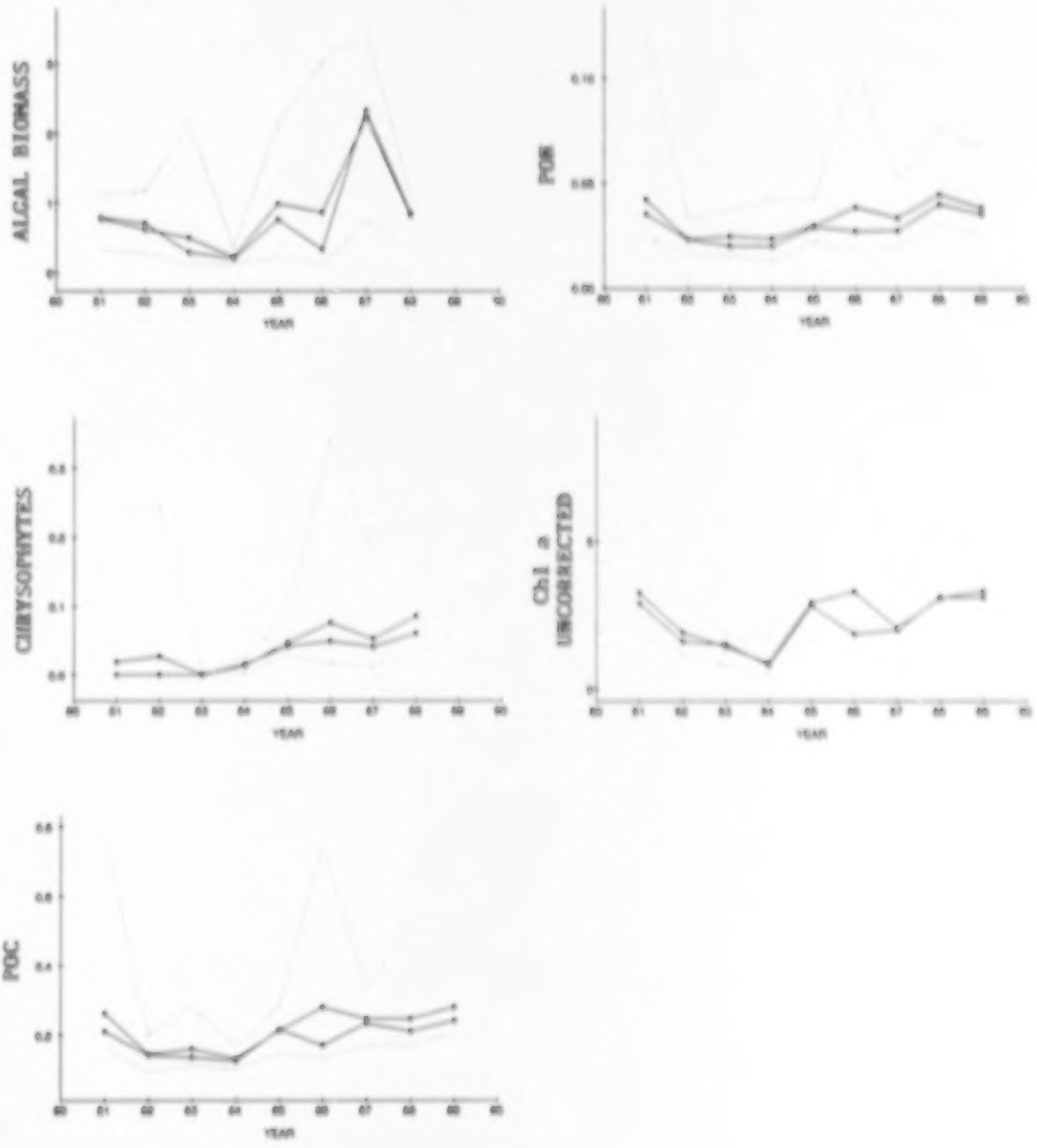

FIG. 6. The biomasses of algae and chrysophytes ($mg.m^{-3}$), and the concentrations of particulate organic carbon (POC), nitrogen (PON) ($mg.L^{-1}$), and chlorophyll a (Chl a) ($ug.L^{-1}$) are presented for the prestratified period for station 41 in the main lake (mean (●), median (○), maximum and minimum (–)).

Bay of Quinte Angling Surveys, 1990

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Lake Ontario Fisheries Unit 1990 Annual Report, LOA 91.1 (Chapter 13)

The Lake Ontario Fisheries Unit conducted angling surveys for Bay of Quinte ice and open-water sport fisheries in 1990. Angling effort during the ice (December 18, 1989 to February 28, 1990) and open-water (May 5 to December 31, 1990) fisheries were 195,589 and 350,588 rod-hours, respectively. Annual angling effort during the ice fishery appears to have stabilized after increasing steadily since 1982, while fishing pressure during the open-water fishery has decreased dramatically after peaking in 1987. No reliable estimate of walleye harvest was determined for the ice fishery because early ice conditions resulted in significant fishing pressure (30% of total ice fishery) occurring in December, prior to the scheduled angling survey. Nonetheless, we speculated that the total ice fishing walleye harvest was similar to 1989 at 20,000 to 25,000 fish. Consistent with the decline in angling effort, walleye harvest during the open-water fishery (89,955) was low compared to recent years. Fishing success remained good with walleye catch-per-unit-effort (number per rod-hour) estimated at 0.101 and 0.488 during ice and open-water fisheries respectively, and having declined only marginally from 1989. The mean fork length of walleye harvested during ice and open-water fisheries was 509 mm (20 in) and 389 (15 in), respectively. Corresponding mean ages were 6.3 and 3.6 yr.

Recommendations

1. The trend of decreasing annual angling effort during the open-water fishery should be monitored closely since alternative walleye harvest allocation strategies could be considered.
2. Consideration should be given to documentation of developing walleye fisheries on the Bay of Quinte which are not currently covered by our angling surveys (e.g. bridge and shoreline angling).
3. Consideration should be given to fishing tournaments as a source of biological data for targeted fish populations, particularly largemouth bass which are not adequately assessed in our current index netting programs.
4. The ice angling survey design should have a flexible starting date to allow for annual variation in formation of favorable ice conditions and the heavy fishing pressure associated with "first-ice".

Introduction

Angling surveys have been conducted on the Bay of Quinte periodically since 1957 (Mathers 1989). Traditionally, walleye make up the bulk of the angling harvest. Fishing pressure on the Bay of Quinte was minimal when walleye populations were very low in the late 1960's and 1970's and no angling surveys were conducted at that time. With the resurgence of walleye since 1978 (Bowlby et al. 1989), a large sport fishery has once again developed on the Bay of Quinte.

The Lake Ontario Fisheries Unit has monitored the Bay of Quinte ice fishery biennially from 1982 to 1988 and annually since 1988, and has monitored the open-water fishery annually since 1979. Survey designs are framed around the walleye open-season. Bay of Quinte angling surveys are designed to estimate angling effort and species-specific catch and harvest, and to collect biological data on sport fish populations. Biological sampling, like the fishery itself, focuses on walleye.

This report summarizes the results of the 1990 ice and open-water angling surveys on the Bay of Quinte and provides comparative data from previous years.

Methods

The basic design and analysis of 1990 ice and open-water angling surveys on the Bay of Quinte were conducted using CREESYS (Lester and Trippel 1985). The angling surveys were stratified by space, day-type (workdays and non-workdays), and season (open-water survey only, see below). The surveys covered the Bay of Quinte from Trenton to Glenora and included 12 geographic strata (Fig. 1).

Ice Fishery

Traditionally, ice cover on the Bay of Quinte develops around January 1 and the ice fishing survey is conducted from about January 1 to the end of the open angling season for walleye (February 28 in recent years). The 1990 ice fishing survey was scheduled to be conducted from Saturday, January 4 to February 28. However, favorable ice conditions developed in early to mid-December, 1989. Therefore, several angler counts were made at this time in order to establish the magnitude of the December 1989

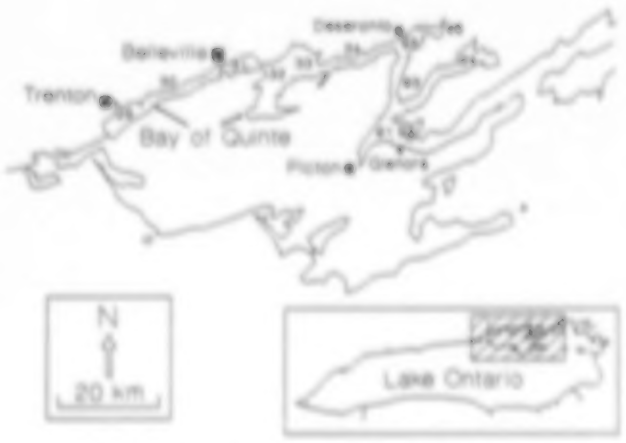

FIG. 1. Twelve geographic areas used in the 1990 Bay of Quinte angling surveys (29-Trenton, 30-Massassawa Island, 31-Belleville, 32-Point Anne, 33-Trident Point, 34-Telegraph Narrows, 95-Deseronto, 96-Napanee River, 93-Long Reach, 94-Hay Bay, 92-Beggar's Bay, 91-Picton Bay.

ice fishery. All angling was assumed to occur between 0700 and 1700 h.

Angling effort

Angling effort was measured using aerial counts. During each flight, 'on-ice' anglers and fish huts were counted separately for each of the 12 geographic areas. Four unscheduled flights were made between December 18 and December 31. Thereafter, two flights were scheduled for each week - one weekend day and one weekday. Of 17 scheduled flights in January and February, 3 were cancelled due to inclement weather.

Angling catch and harvest

Angler interviews and hut occupancy counts were conducted on Big Bay only (*areas* 32 and 33). The estimated catch and harvest of walleye in Big Bay were expanded to determine the walleye catch and harvest for the entire Bay of Quinte based on the geographic pattern of fishing success observed during the 1989 ice fishing survey (Table 1). Interviews were conducted in January and February only. However, local angler diaries of fishing trips made prior to and after January 4, 1990, were used to estimate walleye fishing success in December relative to the remainder of the ice fishing survey. A rough estimate of walleye harvest was thereby determined for December, 1989.

TABLE 1. Ratio of walleye catch and harvest-per-unit-effort (CUE and HUE - number per rod-hour) by all on-ice and ice hut anglers in areas 32 and 33 vs. those of anglers in all other areas (based on data from the 1989 ice fishery).

Angling mode	Ratio	
	CUE	HUE
On-ice	0.871	1.027
Ice hut	0.559	0.773

Fork length tallies were recorded by species for all fish observed. The age composition of harvested walleye was estimated using a fork length/age key determined from fall trapnetting (1989). Of 17 scheduled 'on-ice' interview days, 2 were cancelled.

Open-water Fishery

In recent years, an index survey has been used to assess the open-water fishery. Index surveys involve monitoring portions of the open-water fishery and expanding the results, based on patterns of fishing observed in years of complete survey coverage, to represent the entire walleye open-season. The next complete open-water survey is scheduled for 1993.

The 1990 open-water angling survey was conducted from May 5, the opening-day of the walleye season, to June 3, and again from June 25 to July 22. These time periods correspond to three of the six open-water survey seasons defined by Mathers and Bowlby (1990) (Table 2). All angling was assumed to occur between 0700 and 2000 h on the opening weekend and between 0700 and 2100 h for the remainder of the survey.

Angling effort

Angling effort was determined by a combination of aerial and 'on-water' boat counts. Aerial counts were

TABLE 2. Description of seasons used in the open-water angling survey. Only the opening weekend, May and July seasons were sampled. The other seasons were extrapolated using expansion factors (shown) based on the seasonal pattern of angling effort (rod-hours), walleye catch and walleye harvest observed in 1988.

Season	Effort	Catch	Harvest
Opening weekend (May 5 to 6)	0.176	0.073	0.100
May May 7 to June 3 (next four weeks)	0.330	0.452	0.409
June June 4 to June 24 (remainder of June)	0.073	0.047	0.041
July June 25 to July 22 (week including July 1 + next four weeks)	0.150	0.262	0.263
August July 23 to Sept. 3 (remainder of July to Labour Day)	0.196	0.129	0.156
Fall Sept. 4 to Nov. 31 (remainder of September to end of November)	0.076	0.038	0.031

made during the opening weekend (eight scheduled flights) and each weekend in the May/June season (eight scheduled flights). Two flights were cancelled due to inclement weather.

On-water boat counts were made during weekdays in the May/June season (2/wk) and for all of the July season (4/wk - two each for weekend days and weekdays). To facilitate on-water boat counting, the 12 sampling areas were grouped into two broad areas (upper bay = areas 29, 30, 31, 32, 33 and lower bay = areas 34, 91, 92, 93, 94, 95, 96) such that one of the two broad areas was covered during each on-water boat count. Of 24 scheduled on-water boat counts, seven were not completed due to weather or equipment problems. Of these seven, partial on-water boat counts (i.e. some areas only) were made on two days and boat counts from shore were made on the remaining five days.

Angling effort was extrapolated to the entire open-water angling season from May 5 to December 31, 1990, based on 1988 data (Mathers 1989, Table 2). Note that open-water angling effort in December was considered negligible.

Angling catch and harvest

Angler interviews were conducted on all geographic areas to estimate species-specific catch and harvest rates and to collect biological data on major sport fish populations. During the opening weekend, fork length tally information was collected for all walleye observed. Thereafter, biological sampling included a fork length and scale sample for age interpretation from a random sample of walleye. Walleye greater than 9-yr-old were grouped into one category because of the difficulty of age interpretation using scales from these older fish. Length tally information only was collected for all other species observed in the anglers harvest. The number and approximate size of all walleye released by anglers was also recorded. Anglers were shown actual size illustrations of 1, 2 and 3-yr-old walleye and asked to estimate which illustration mostly closely corresponded to the size of each fish released.

Comparisons to Past Surveys

Angler effort and walleye harvest data from previous years' surveys were presented for comparison to the 1990 ice and open-water fisheries. The 1983 open-water survey data were not reported because angler effort estimates were judged unreliable. The 1987 open-water angling effort and walleye harvest estimates were re-calculated using the fishing patterns observed in 1988 rather than the 1982 patterns used for the original analysis (Mathers 1988).

Results and Discussion

Ice Fishery

Angling effort

Angling effort during the 1990 ice fishery (December 18, 1989 to February 28, 1990) was 195,589 rod-hours (Table 3). Annual ice fishing pressure appears to have levelled off after a steady increase since the early 1980's (Fig. 2). Previous years' estimates were based on fishing during January and February only, fishing effort in December being considered negligible due to poor ice conditions.

TABLE 3. The estimated angling effort (rod-hours), walleye catch and walleye harvest for the 1990 angling surveys on the Bay of Quinte.

Season[a]	Angling effort	Walleye catch	Walleye harvest
Ice Fishery			
December (1989)	59079	N/A	N/A
January/February	136510	17082	11135
Open-water Fishery			
Opening weekend	47254	19895	12632
May	135859	88079	42809
June[b]	25764	8055	3704
July	46652	26541	14013
August[b]	68572	23019	14033
Fall[b]	26486	6425	2764
Ice fishing total	195589	N/A	22500[c]
Open-water total	350588	171014	89955
Annual Total	546177	N/A	112455

[a]See Methods for definition of seasons.
[b]Estimate based on the seasonal pattern observed in 1988.
[c]"Ballpark" estimate based on observed angling effort and predicted fishing success based on angler diaries.

FIG. 2. Angling effort (rod-hours) during the Bay of Quinte ice and open-water fisheries from 1957 to 1990.

However, because of early ice formation in December 1989, we estimated that 59,079 rod-hours (30% of total ice fishery) were exerted from December 18, 1989 to January 3, 1990.

On-ice anglers and ice hut anglers accounted for 43 and 57% of the total angling effort, respectively. Most on-ice angling occurred in the areas of Long Reach, Trident Point, Point Anne, Belleville and Deseronto. Fishing pressure continues to increase in Long Reach (area 93) especially near Sherman's Point at the mouth of Hay Bay. As in previous years, most ice huts were concentrated near Trenton, Makatewis Island, Belleville, Point Anne and Tri-

dent Point. Total numbers of ice huts peaked at 1037 in mid-January.

Angling catch and harvest

Anglers harvested 3,473 (83%) of 4,165 walleye caught in Big Bay. Northern pike, white perch and yellow perch were also present in the anglers catch and harvest (Table 4). Yellow perch were particularly abundant.

The estimated catch and harvest of walleye for the entire Bay of Quinte based on the expansion of the Big Bay data were 17,082 and 11,135, respectively for the Jan.4 to Feb. 28, 1990 time period (Table 3). Our angling survey did not include walleye catch and harvest estimates for the fishing effort observed in December 1989. Local angler diaries indicated that catch rates were higher early in the ice fishing season (December). Given that 30% of total ice fishing effort occurred at this time, the catch and harvest during December, 1989 were likely similar to those for the remainder of the 1990 ice fishery. It is our view that the walleye harvest during the 1990 ice fishery was similar to or slightly higher than that observed during the 1989 ice fishery, probably about 20,000 to 25,000 fish (Fig. 3).

The estimated catch-per-unit-effort (CUE) and harvest-per-unit-effort (HUE - number per rod-hour) by walleye fishermen were 0.101 and 0.084, respectively, having declined only slightly from 1989 (Fig. 4).

Biological attributes of the walleye harvest

The mean fork length and weight of walleye harvested during the ice fishery were 509 mm (20 in) and 1,959 g (4 lb 5 oz) respectively. The range in fork lengths observed was 140 to 780 mm (n = 138, Fig. 5). Age-classes 3 to 8 were all well represented in the harvest with 4-yr-old walleye being most abundant (Fig. 6). A large number of fish older than 9 yr of age were also caught, most of which probably belong to the 1978 year-class (12-yr old). The mean age of harvested walleye was 6.3 yr.

Open-water Fishery

Angling effort

Angling effort during the 1990 open-water fishery (May 5 to December 31, 1990) was 350,588 rod-hours (Table 3), a decline of 27% from 1989. Fishing pressure declined in all seasons sampled.

Annual open-water fishing pressure has declined steadily since 1987 (Fig. 2). Mathers and Bowlby (1990) speculated that the downward trend was related to the growth of the salmonid fishery near Wellington and Brighton. The salmonid fishery in Lake Ontario's outlet basin has also grown in past years (Stewart et al. 1990).

The low angling effort in 1990 can at least in part be attributed to poor weather conditions. During the 1990 open-water survey, 38% of the days sampled were judged by survey technicians to have weather conditions that would adversely affect fishing pressure compared to only 7% during the same time period in 1989.

Since fishing success has not declined (see below), it seems likely that the downward trend in angling effort cannot be attributed to angler dissatisfaction associated with a decline in walleye abundance.

TABLE 4. Estimated catch and harvest of fish in Big Bay (areas 32 and 33) by all anglers from Jan. 4 to Feb. 28, 1990. Standard error of the estimate is shown in brackets.

Species	Catch		Harvest	
Northern pike	66	(35)	66	(35)
White perch	38	(31)	35	(31)
Yellow perch	13159	(2196)	6799	(1004)
Walleye	4165	(1293)	3473	(1129)

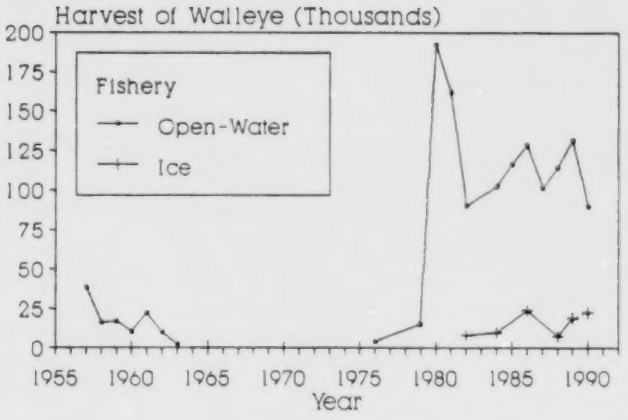

FIG. 3. Walleye harvest during the Bay of Quinte ice and open-water sport fisheries from 1957 to 1990.

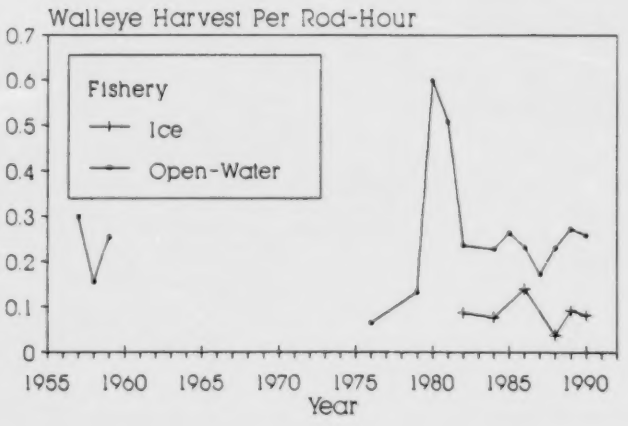

FIG. 4. Walleye harvest per rod-hour of angling effort during the Bay of Quinte ice and open-water fisheries from 1957 to 1990.

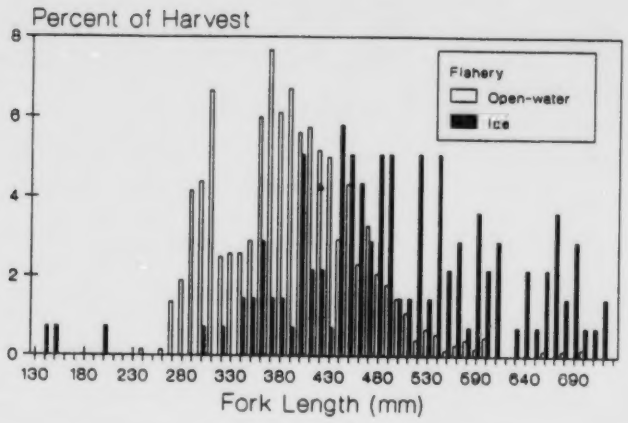

FIG. 5. Percent of walleye harvest contributed by 10 mm fork length-classes during the Bay of Quinte ice and open-water fisheries in 1990.

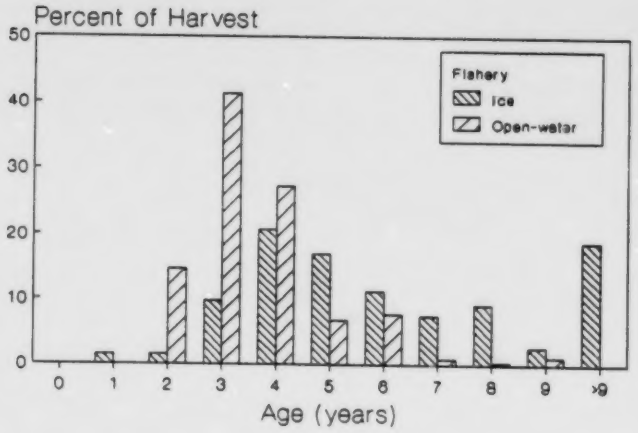

FIG. 6. Percent of walleye harvest by age-class during the Bay of Quinte ice and open-water fisheries in 1990.

Angling catch and harvest

Consistent with the decline in angling effort, the catch (171,014) and harvest (89,955) of walleye during the 1990 open-water season were also low compared to recent years (Table 3, Fig. 3). However, fishing success remains very good (CUE and HUE were 0.488 and 0.257, respectively), having declined only marginally from 1989 (Fig. 4).

Biological attributes of the walleye harvest

The mean fork length and weight of walleye harvested during the 1990 open-water fishery were 389 mm (15 in) and 803 g (1 lb 12 oz), slightly larger than the previous summer. Both the mean size and the range of sizes observed were smaller in the open-water fishery compared to the ice fishery (Fig. 5). The peak in Fig. 5 corresponding to a fork length of about 300 mm represents 2-yr-old fish recruiting to the open-water sport fishery.

As in past open-water fisheries, 3-yr-old walleye followed by 4 and 2-yr-olds respectively, were most abundant in the angler's harvest (Fig. 6). The mean age of harvested walleye was 3.6 yr.

Of 553 walleye sampled during the open-water fishery, only 108 were sampled in July. More walleye should be sampled during July in future years to ensure that all seasons are adequately covered.

Information gathered on the size of released walleye suggested that 1-yr-old walleye were most frequently caught and released (Fig. 7). Initial inspection of Fig. 7 suggests a strong year-class of 1-yr-old fish but we suspect that our method of gathering data on the size of walleye released by anglers has underestimated the true size. Many, if not most, of the 1-yr-old walleye may actually have been 2-yr-olds. In future surveys, we will attempt to refine our method of determining the size/age of walleye released by anglers.

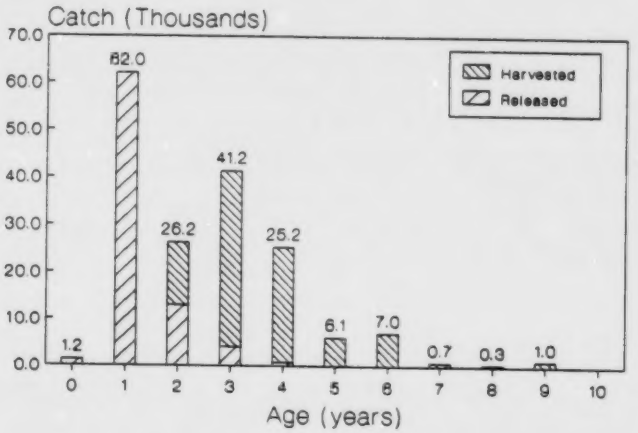

FIG. 7. Total numbers of walleye harvested and released by age-class during the 1990 open-water sport fishery.

Survey Design Issues

1) Thirty percent of the total ice fishing pressure on the Bay of Quinte occurred in December, 1989 due to unusually early ice formation. Fishing pressure in December had previously been considered negligible. Future ice fishing survey designs should have a flexible starting date to allow for the possibility of early ice formation.

2) Walleye fisheries, not covered by our current Bay of Quinte angling survey designs, have developed in recent years. Three such fisheries which occur in late fall, include: 1) anglers fishing from the bridge that crosses the Bay of Quinte at Belleville (Norris Whitney Bridge); 2) anglers fishing from Meyer's Pier in Belleville; and 3) shore anglers fishing in Picton Harbour. A fourth popular walleye shoreline fishery occurs below the first dam on the Trent River every spring. Documentation of such fisheries should be carried out to determine their relative contribution to the total walleye harvest from the Bay of Quinte.

3) Several fishing tournaments are now conducted annually on the Bay of Quinte. We have not collected any information (catch statistics, biological data etc.) from these tournaments to date. Walleye, smallmouth bass and

largemouth bass are all targeted. Of particular interest are largemouth bass which are conspicuously absent from our index netting programs on the Bay of Quinte but of which healthy populations apparently reside in areas such as Muscote Bay and Hay Bay. Thus, bass fishing tournaments are a potential source of biological information for largemouth bass.

Management Implications

1) Walleye release rate during the open-water fishery on the Bay of Quinte has increased steadily since 1981 (Mathers 1989). Forty-seven percent (over 81,000) of walleye caught during the 1990 open-water fishery were released by anglers. In our view, the large numbers of young walleye released by anglers during the open-water fishery (Fig. 7) will prove significant in maintaining walleye population stability in the Bay of Quinte.

Most older walleye migrate out of the Bay of Quinte to eastern Lake Ontario after spawning (Bowlby et al. 1989), effectively escaping the open-water fishery. These older fish migrate back into the Bay of Quinte in the fall and are vulnerable to the ice fishery but only about 10 to 20% of the annual harvest occurs at this time (Table 3; Mathers 1989). Young fish, by contrast, are very vulnerable to angling throughout the year.

The migration of large walleye to Lake Ontario for the summer months combined with the high release rate of young walleye and low mortality of angler-released walleye (Schaefer 1989) should ensure continued maintenance of healthy spawning populations in the Bay of Quinte.

2) Sport fishing pressure during the Bay of Quinte open-water fishery has decreased steadily since 1987. Decreased annual walleye yields will result if this trend continues. In such an event, managers may wish to consider adjustment of regulatory strategies or walleye harvest allocations to various user groups. However, given the imminent invasion by zebra mussel (*Dreissena polymorpha*) and the unknowns associated with their impact on the Bay of Quinte fish community, a conservative approach is strongly advised.

Acknowledgements

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Lake Whitefish Spawning Shoal Observations at Four Bay of Quinte and Eastern Lake Ontario Sites

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Dive surveys were conducted on three eastern Lake Ontario lake whitefish (*Coregonus clupeaformis*) spawning shoals. Egg deposition was verified at the two Bay of Quinte sites surveyed. More eggs were found at the Makatewis Island site (11.8 eggs/sample) than at the Trident Point site (1.8 eggs/sample), possibly due to better spawning substrate at Makatewis Island. Only a small portion of the Lake Ontario site (Gull Bar) was surveyed, and only a single dead lake whitefish egg was found. A fourth suspected spawning shoal (Petticoat Point, near Gull Bar) was not surveyed due to weather and time constraints. Zebra mussel (*Dreissena polymorpha*) were not observed at any site. Recommendations for future lake whitefish spawning shoal studies were made.

Recommendations

1. Conduct lake whitefish fry emergence trapping and larval fish sampling studies at the two Bay of Quinte spawning sites, Makatewis Island and Trident Point.
2. Conduct preliminary substrate mapping studies to focus efforts for further egg deposition verification studies at the two Lake Ontario spawning sites, Gull Bar and Petticoat Point.
3. Consider further lake whitefish egg deposition verification studies on the Bay of Quinte, e.g. north shore of Big Island including Big Island Shoal, Snake Island, Trent River and Way Point.
4. Monitor zebra mussel colonization on confirmed lake whitefish spawning shoals.
5. Evaluate lake whitefish production (i.e. egg density and survival) with respect to micro-environmental conditions (e.g. substrate type, interstitial water quality) on spawning shoals.

Introduction

Most lake whitefish (*Coregonus clupeaformis*) in Lake Ontario are found in the eastern end of the lake (Christie 1967) where habitat, particularly spawning habitat, is most suitable. Lake whitefish abundance in eastern Lake Ontario has increased in recent years (Stewart 1991).

The eastern Lake Ontario lake whitefish population is supported by two major spawning stocks, one which migrates into the Bay of Quinte to spawn, the other which spawns in Lake Ontario, mostly along the south shore of Prince Edward County. The stocks spawn in late October and November with the Bay of Quinte stock spawning somewhat earlier, typically the last week in October and the first week of November, than the Lake Ontario stock which spawns around mid-November. The two stocks cohabit in the eastern outlet basin of Lake Ontario for the remainder of the year (Christie 1967).

Mark-recapture population estimates indicate that the Bay of Quinte spawning stock population size has increased tremendously in recent years (Bowlby 1990). The current status of the Lake Ontario spawning stock is not as well known (Stewart 1991).

The two lake whitefish stocks are morphologically as well as behaviorally divergent (Ihssen et al. 1985). Ongoing research will soon allow routine discrimination of these stocks in index netting programs on eastern Lake Ontario (Casselman 1990).

A potential threat to lake whitefish stocks in eastern Lake Ontario is zebra mussel (*Dreissena polymorpha*). Moderate numbers of zebra mussel were observed along Lake Ontario's west and south shores in the summer of 1990 and isolated individuals have been recorded throughout the lake, including the Bay of Quinte (Schaner 1991).

Lake whitefish spawning habitat is vulnerable to colonization by zebra mussel, possibly making spawning substrate less suitable for egg survival and fry production. Potential impacts of zebra mussel colonization on lake whitefish spawning success include: (1) competition for space between zebra mussel and lake whitefish eggs, (2)

impairment of whitefish egg survival due to degraded substrate and water quality caused by zebra mussel waste products, and 3) impairment of larval whitefish survival due to zebra mussel impact on zooplankton community structure (Freeberg et al. 1990).

In order to monitor the colonization and assess the impact of zebra mussel on eastern Lake Ontario lake whitefish populations, four putative lake whitefish spawning shoals were chosen for study. This report summarizes the results of dive surveys, conducted following lake whitefish spawning in 1990-91, and designed to: (1) verify egg deposition and determine egg density, (2) determine the presence/absence of zebra mussel, and (3) characterize spawning substrate at these four shoals.

Methods

The four lake whitefish spawning shoals chosen for study (two in the Bay of Quinte and two in Lake Ontario, Fig. 1) are detailed in Table 1. The shoals were identified based on whitefish spawning behavior (Goodyear et al. 1982a; Scott and Crossman 1973), historical records (Hart 1930; Goodyear et al. 1982b), unpublished data from the Lake Ontario Fisheries Unit, and interviews with commercial fishermen and former Ontario Ministry of Natural Resources employees.

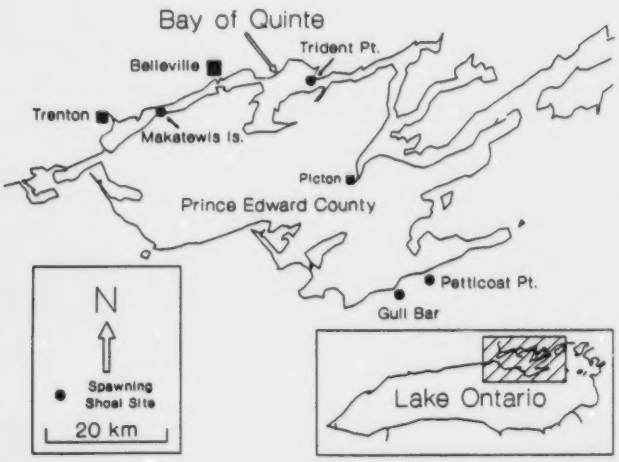

FIG. 1. Lake whitefish spawning shoal study sites in eastern Lake Ontario and the Bay of Quinte.

Previous studies have not been conducted on these shoals, hence, the primary objective was to verify the presence of lake whitefish eggs. The exploratory nature of the shoal survey design reflected this objective.

Shoal Surveys

To facilitate a systematic search for lake whitefish eggs at each shoal, the following procedure was adopted. Permanent shoreline reference markers were established. Transects (100 to 300 m each) were laid out at precise angles using a survey transit. A Loran C was used in Lake Ontario to verify transect positioning. A visual inspection of transect lines was made by SCUBA/snorkel divers at the Bay of Quinte sites and by a helmeted diver in Lake Ontario. Substrate characteristics (Wentworth 1922) and the presence/absence of zebra mussel were described by the diver over radio.

Egg samples

Egg samples were collected using a custom-made suction sampler designed for use in shallow water (Integrated Explorations, Environmental Research Consultants, 189 McCurdy Rd., Box 1385, Guelph, Ontario). The suction sampler had a 10 cm diameter mouth opening, and when employed, was assumed to collect all eggs within a 10 cm diameter circle of substrate. Five such sub-samples were pooled to form one sample which represented the number of eggs/0.04 m^2 sampled (assuming that the sampling device was 100% efficient). The five sub-samples were taken from habitat most likely to contain lake whitefish eggs (e.g. gravel pockets, depressions etc.) within a 1 m radius circle located at uniformly spaced intervals along the established transect lines. Interval distances varied somewhat between transects depending on the substrate type and total distance to be surveyed.

The suction sampler had a 500 u mesh bag to collect egg samples. A 1 mm mesh sieve was used for subsequent sorting and picking of eggs from each sample. Eggs were preserved in Gilson's fluid (Bagenal 1978).

Lake whitefish egg density is reported here as the total number per sample. These egg densities were not expanded to estimate the actual egg density on the entire spawning shoal because the five sub-samples comprising each sample were not collected at random. Rather, the egg counts reported here represent egg densities in areas

Table 1. Location, approximate surface area, and dive survey dates of the four lake whitefish spawning shoal study sites.

	Latitude/longitude	Area (ha)	Survey dates
Bay of Quinte Shoals			
Makatewis Island	44°07'N 77°30'W	2.0	Nov. 29 to Dec. 1, 1990
Trident Point	44°09'N 77°14'W	6.0	Nov. 27 to Dec. 7, 1990
Lake Ontario Shoals			
Gull Bar	43°51'N 77°05'W	260.0	Jan. 28 to Jan. 30, 1991
Petticoat Point	43°52'N 77°02'W	154.0	Not Surveyed

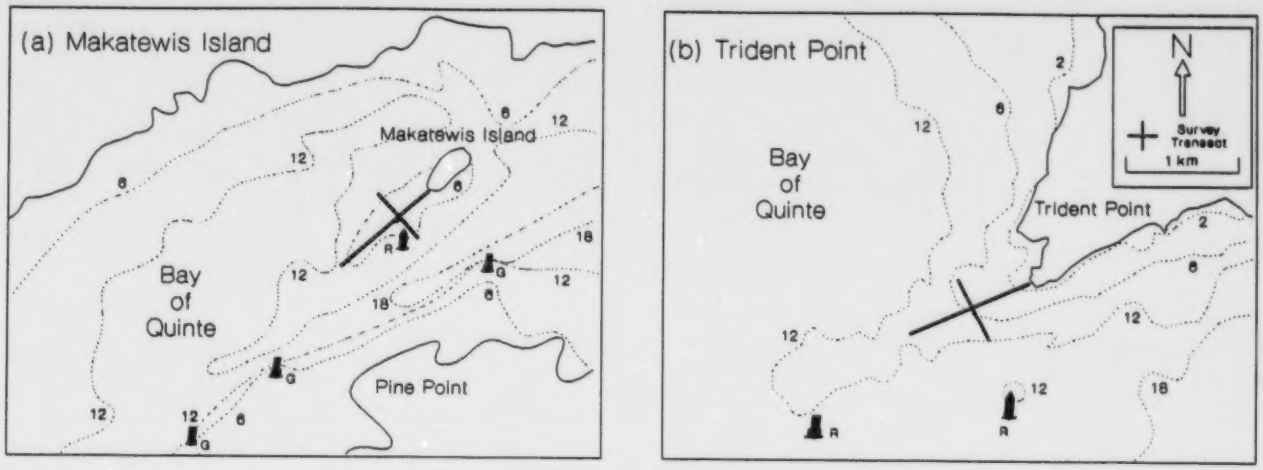

FIG. 2. Location of dive survey transects at Bay of Quinte study sites: (a) Makatewis Island, and (b) Trident Point. Depth contours are in ft. Navigational markers are shown (R = red, G = green).

with substrate judged most suitable for spawning. The egg counts were used to compare egg density among shoals, assuming that the egg sampler was equally efficient at each shoal.

Results

Diving operations were continually hampered by bad weather during this study. As a result, more time was expended at the Bay of Quinte sites than was initially intended. The dive survey was called off at the end of January, 1991 with only a small portion of the proposed work completed at the Lake Ontario, Gull Bar site and no information collected from the Petticoat Point site.

Egg Samples

Makatewis Island

The dive survey at the Makatewis Island shoal took place from November 29 to December 1, 1990 (Table 1). Divers established and surveyed three, 300 m transects (Fig. 2). A total of 368 lake whitefish eggs were collected in 31 samples (mean = 11.8 eggs/sample; S.E. = 2.2; range = 0-55; Table 2). Five samples contained no eggs (Fig. 3). When samples with no eggs were eliminated, the mean number of eggs/sample was 14.2 (S.E. = 2.4). Over 90% were judged to be live eggs. Eggs judged to be alive were translucent while opaque eggs were considered dead. Egg samples were collected at a water depth ranging from 1.0 to 12.0 ft (mean = 5.0 ft).

TABLE 2. Summary of data collected at lake whitefish spawning shoal study sites.

	Makatewis Island	Trident Point	Gull Bar
Distance Surveyed (m)	900	750	300
No. of egg samples	27	31	18
No. of eggs collected:			
Total	368	49	1
Mean (S.E.)	11.8 (2.2)	1.8 (0.4)	0.1 (0.1)
Range	0 - 55	0 - 7	0 - 1
% alive	90.2	98.0	0.0
Water depth at location of egg samples:			
Mean	5.0	7.2	13.3
Range	1.0 - 12.0	0.5 - 14.0	11.5 - 15.5
Zebra mussel (present/absent)	Absent	Absent	Absent

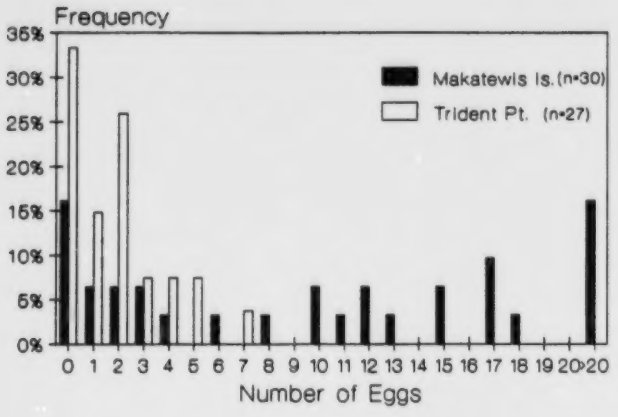

FIG. 3. Numbers of lake whitefish eggs found in each sample taken at Bay of Quinte study sites.

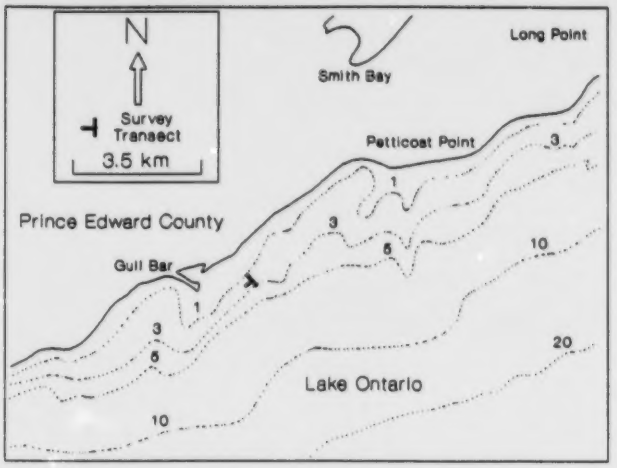

FIG. 4. Location of dive survey transects at the Lake Ontario Gull Bar study site. Depth contours are in fathoms.

Trident Point

The dive survey at the Trident Point shoal took place over the time period November 27 to December 7, 1990. Divers established and surveyed two, 300 m transects and one 150 m transect (Fig. 2). A total of 49 lake whitefish eggs were collected in 27 samples (mean = 1.8 eggs/sample; S.E. = 0.4; range = 0-7; Table 2). Nine samples contained no eggs (Fig. 3). When samples with no eggs were eliminated, the mean number of eggs/sample was 2.7 (S.E. = 0.4). Ninety-eight percent were judged to be live eggs. Egg samples were collected at a water depth ranging from 0.5 to 14.0 ft (mean = 7.1 ft).

Gull Bar

The dive survey at Gull Bar took place from January 28 to 30, 1991. Divers established and surveyed three, 100 m transects (Fig. 4). One dead lake whitefish egg was found in 18 samples (Table 2). Egg samples were collected at a water depth ranging from 11.5 to 15.5 ft (mean = 13.3 ft).

Petticoat Point

Diving operations were not carried at Petticoat Point due to weather delays and the lateness of the season.

Substrate Characteristics

Substrate characteristics varied widely among spawning shoals. Preliminary analysis of substrate characteristics indicated that the Makatewis Island site had substrate most suitable for lake whitefish spawning. Here, lake whitefish eggs where found scattered across a wide area (84% of egg samples taken over a distance of 900 m surveyed contained eggs). The substrate consisted predominately of a thin layer of gravel or flat limestone cobble over limestone bedrock. Whitefish eggs were even found in clam beds. The Trident Point site was judged less suitable for lake whitefish spawning. Although the site afforded a wide range of substrate conditions (e.g. primarily bedrock, crevices and pockets of gravel, sand and clam shell deposits), only a small portion of the site had good spawning substrate (eggs were found in 65% of the samples taken over a distance of 750 m, but there was generally only one or two eggs/sample). The Gull Bar site consisted mainly of smooth limestone bedrock with 5 to 10 cm crevices, and only sporadic occurrences of depressions or pockets containing gravel and small cobble. Therefore, this site was judged the least suitable, of the three surveyed, for lake whitefish spawning.

Zebra Mussel Presence/Absence

Zebra mussels were not found at any of the three sites surveyed.

Discussion

Bay of Quinte Sites

Lake whitefish egg deposition was confirmed by dive surveys at two Bay of Quinte sites, Makatewis Island and Trident Point, although higher egg densities and better spawning substrate were found at the Makatewis Island site. The diversity of substrate types and high egg densities at Makatewis Island provide an opportunity for future research designed to evaluate lake whitefish production in a variety of micro-environmental conditions (e.g. substrate types and interstitial water quality). Classic substrate types such as crevices, sorted gravels, flat cobbles, clam beds and the undersides of flat rocks could be compared on the basis of egg density and survival. Research information of this type would advance spawning shoal exploratory efforts, by narrowing down substrates with greatest potential to yield egg samples, and allow quantification of a shoal's reproductive potential.

Follow-up fry emergence trapping (e.g. Collins 1975) and larval fish sampling studies (e.g. Cucin and Faber 1985; Hulsman and Loftus 1984; Loftus 1982) should be conducted in the spring of 1991 at both sites. Further dive surveys are required to verify egg deposition at other Bay of Quinte sites. Large catches of lake whitefish in trapnets, during the spawning period, at Big Island, Snake Island, Trent River and Way Point (Mathers 1991), implicate these areas as spawning site candidates.

Lake Ontario Sites

The areas identified for study as potential lake whitefish spawning shoals in Lake Ontario were much larger than the Bay of Quinte site, and only a small portion of one site was surveyed by divers during the present study. Although one dead egg was found, little suitable spawning substrate was observed. Further exploratory dive surveys should be conducted during the summer (i.e. fair-weather conditions) to locate and mark suitable spawning habitat (e.g. more frequent gravel pockets or unique and extensive areas of sorted gravel and cobble) before any future attempts are made to quantify lake whitefish egg deposition at the Lake Ontario sites. During favorable working conditions, large areas of potential spawning shoals could be systematically searched by "towing" a diver, equipped with radio communications, on a sled along established transects.

Management Implications

This study represents the first attempt to locate and verify egg deposition on eastern Lake Ontario lake whitefish spawning shoals since the 1920's (Hart 1930). The incentive to undertake this work was provided by the uncertainties associated with zebra mussel colonization on lake whitefish spawning shoals and the resultant impacts on lake whitefish production. Because zebra mussel were not found during the dive surveys reported here, the results represent the status of lake whitefish spawning shoals prior to zebra mussel colonization. The method of collecting egg samples used in this study can easily be repeated in future years to assess lake whitefish egg deposition following zebra mussel colonization on spawning shoals.

Follow-up work should be conducted to develop lake whitefish fry/larvae/young-of-the-year abundance indices. In addition, zebra mussel colonization on lake whitefish spawning shoals should be monitored and the resultant impact on lake whitefish production assessed.

Acknowledgments

Thanks to the divers from Integrated Explorations for conducting the spawning shoal surveys under extremely adverse working conditions. Brian Malone gathered the background data required to identify potential lake whitefish spawning shoals. Thanks to Tom Stewart and Steve Kerr for reviewing the manuscript, Carol Ward for copy editing, and Linda Balsillie for publishing.

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Lake Ontario Hydroacoustic Survey for Alewife and Smelt

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Lake Ontario Fisheries Unit 1990 Annual Report, LOA 91.1 (Chapter 15).

A hydroacoustic survey of alewife and smelt was conducted in the Canadian western basin of Lake Ontario. Ninety-three percent of the detected targets were the same size as alewife and smelt. The total number of targets was estimated to be 819 million, approximately twice the combined number of alewife and smelt estimated from midwater trawls. Comparison of the acoustic data with simultaneously collected trawl data suggested that the trawl efficiencies may vary with depth and species, affecting the assumptions necessary to partition the data by species.

Recommendations

1. Start using hydroacoustics in assessment of Lake Ontario forage stocks.
2. Collect concurrent dual-beam and echo-integration data, to provide flexibility in post-stratification, thereby minimizing variance of the echo integrator scaling factor.
3. Solve ground-truthing problems caused by varying efficiency of the midwater trawl, and contamination of deep trawls with near-surface fish.
4. Examine seasonal patterns of alewife and smelt distribution to determine the optimum timing for the survey, considering the following factors: spatial segregation of the species, presence of the young-of-the-year, and distribution away from surface and bottom.

Introduction

Assessment of alewife (*Alosa pseudoharengus*) and smelt (*Osmerus mordax*) populations in Lake Ontario has traditionally been done in spring and early summer surveys, using bottom trawls (O'Gorman et al. 1991). Large areas on the Canadian side of the lake cannot be surveyed this way because the bottom is too rough. Since 1988, midwater trawling in the summer has been investigated as an alternative technique. This culminated in a lake-wide survey in 1990 (Mathers et al. 1991).

Acoustic methods have been successfully used on other lakes to assess populations of forage fish species (Burczynski et al. 1987). The midwater trawling program carried out in 1990 provided a convenient framework for an acoustic survey, and it was felt that combining the two techniques would result in valuable information. Therefore, Canadian BioSonics, LTD. was contracted to come on board the trawling vessel and collect acoustic data in two of the nine midwater trawling locations.

The survey has generated a formidable amount of data, and the results presented here are summarized to a high degree. Extensive and detailed information in the form of tables and graphic summaries can be found in the survey report prepared by BioSonics (Anononymous 1991).

Methods

Six transects were surveyed between July 20 and 26, 1990, three at Cobourg and three at Port Credit (Fig 1). The transects at each port originated

just outside the harbour, and ran outwards in three directions. The lengths of the transects varied between 17 and 30 km. Each transect took one night to complete, and consisted of two parts: the outbound leg of the journey was used to collect dual-beam data, and to perform midwater trawls (details in Mathers et al. 1991), and the return leg, along the same path, was used to collect echo-integration data. This sequence was reversed on transects 3 and 11. The dual-beam data were collected both during the trawls at 3.7 km/h (2 kn) and during the runs between trawls at 11.1 km/h (6 kn). The echo-integration data were collected at 11.1 km/h (6 kn).

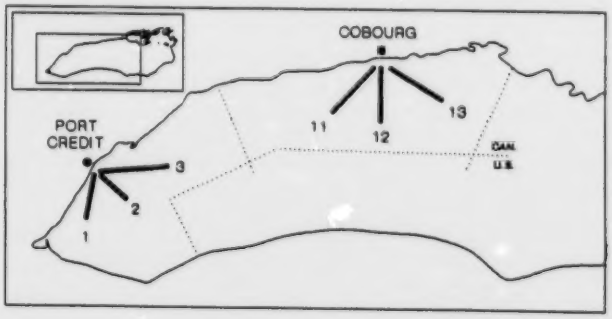

FIG. 1. Locations of the hydroacoustic and trawling transects. The boundaries outline areas that were used to estimate total target populations.

The acoustic data were collected and analyzed by Canadian BioSonics, LTD. The field equipment consisted of a BioSonics 420 kHz Scientific Echosounder, and a 420 kHz dual-beam transducer with nominal beam widths of 6 and 15° (see Appendix A for brief explanation of acoustic methods and terms). The transducer was towed 1 m below the surface, and all depth references in this document are therefore 1 m less than the actual depth. The echo signal data were stored on digital audio tape cassettes, and later analyzed in the laboratory using BioSonics Echo Signal Processor. The echo integrator averaged echo returns by 2 m depth categories between 1 and 101 m below the transducer, and by 1 min time intervals. The echo integrator scaling factor, needed to convert the echo returns into fish densities, was obtained by pooling depth-specific dual-beam results from the entire corresponding transect.

Subsets of the data were used to examine various questions. The comparison of fish density estimates from dual beam with those from echo integration was based on dual-beam data collected during trawls, and echo-integration data collected at the corresponding bottom depths during the other leg of the same transect. This means that the time difference between collection of the two types of data varied between negligible at the offshore end of the transect (trawl and collect dual beam, then immediately turn around to collect echo integration) to 6 h at the nearshore stations. The same subset of echo-integration data were used in examining the temperature and depth distribution of target densities, and since temperature data were collected during trawls, the same time differences existed. The results of the comparison between dual beam and echo integration justified the use of dual-beam data in comparing acoustics with trawling, and again, only the dual-beam data collected during trawls were used.

The transect profiles of target densities were generated from echo-integrator outputs averaged by 2 min, in order to smooth out some of the variability, and present a clearer picture.

Areal density values ($\#/m^2$) were obtained by summing volumetric densities ($\#/m^3$) from individual 1-min outputs over the entire water column. The resulting values were categorized by bottom depth (0-20 m, 20-30 m, 30-40 m, 40-80 m, and 80+ m), and used in a nested ANOVA to examine differences between ports and transects. To estimate population sizes, the data from the three transects within each port and bottom depth category were pooled, and the mean areal density was multiplied by the corresponding lake surface area.

The 1-min areal density values were assumed to be measured free of error, and all statistics relating to error were based only on the variability between the 1-min values. This approach disregards an error component that originates in the dual-beam analysis, and enters density estimates through the echo integrator scaling factor. In a homogenous population of fish it is likely to be small (Burczynski and Johnson 1986).

Results

Sizes of Fish

The distribution of target strengths pooled from the entire survey indicates that the majority of the echoes came from small fish (Fig. 2). The target strength is related fish size, and according to Love's (1971, cited in Burczynski and Johnson 1986) general formula[1], the peak of the distribution at -46 dB corresponds to a 100 mm fish. The range of the distribution corresponds closely to the range represented by the populations of alewife and smelt, including the young-of-the-year (YOY). Burczynski et al. (1987), however found that YOY smelt sizes, similar to those in Lake Ontario, produced target strengths extending to a much lower range than anticipated from application of Love's formula to trawl catches. They interpreted the finding as an error due to the formula's attempt to generalize across all species. It is also commonly found (e.g. Burczynski and Johnson 1986) that measured target strengths distributions are wider than anticipated from converting length frequency distributions of fish to target strength values. It is therefore possible that the sizes that seemingly represent the YOY alewife and smelt, are actually due to larger alewife and smelt, and that the YOY of either species were under-represented in the acoustic data. They are thought to inhabit the uppermost layer in the water column, which was not targeted in this survey. Also, YOY may have been scarce during the survey - trawls made during acoustic sampling contained fewer YOY than trawls made later in other parts of the lake.

Some large targets were also detected. The largest alewife (175 mm) would theoretically give a -40 dB target, and most of the targets above this value were presumably due to larger fish, such as salmonines and coregonines. They represented 7% of the total detected targets.

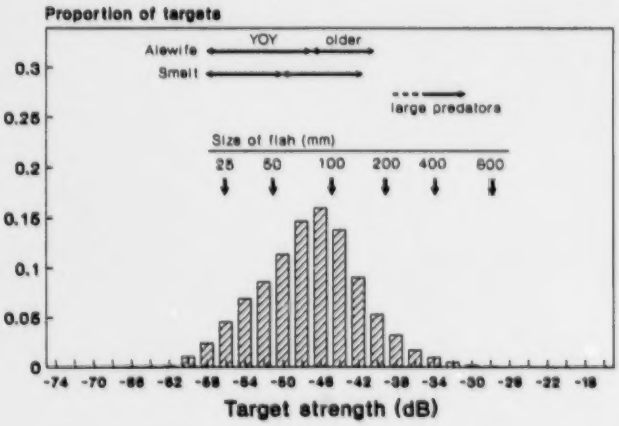

FIG. 2. Distribution of target strengths, data pooled from the entire survey. Corresponcence to species and sizes of Lake Ontario fish was derived through Love's equation.

1 *With a 420 kHz system: target strength (dB) = 19.1 log$_e$ fish length (cm) - 43.36*

Spatial Distribution of Fish

Most of the fish were found in the upper depths of the water column. Figure 3 shows fish density estimates from a subset of echo-integrator sequences for which temperature profiles were also known. These sequences are fairly representative of all transects and bottom depths. The fish densities in the warm water, above 17°C, were variable, the densities between 11 and 17°C tended to be high, and densities below 11°C tended to be low. The same density data, interpreted in terms of water depth, showed low densities in the uppermost layers of the water column, high densities at 6 to 8 m (remarkable in their low variability), and decreased densities deeper in the water column.

The sizes of targets varied with depth (Fig. 4). Targets from the upper 10 m tended to include a wide range of sizes, including large proportions of [2] targets smaller than -50 dB (sizes corresponding to YOY), and targets larger than -40 dB (fish larger than alewife and smelt). The distribution of sizes tended to become narrower deeper in the water column, with the bulk of targets remaining in the alewife/smelt size range.

A more complete picture of distribution patterns is seen in Fig. 5, showing density profiles of the individual transects. High density bands were found near the surface, centered around 6 to 12 m. The densities were low offshore except near surface. Invariably, there was an increase in densities in the nearshore areas, with the high or intermediate densities, normally encountered near surface, extending to the bottom as deep as 50 to 75 m. In the extreme case of transect 13 there was a second high-density band hugging the bottom, and a region of lower densities between the surface and bottom bands.

Differences Between Ports and Transects

Differences in areal density estimates between ports, and between transects within ports were examined in nested ANOVAs ($\log_e$ transformed data, transects nested within ports, separate analysis for each depth category). The results revealed significant differences between transects within ports at all bottom depths. Differences between ports were significant only at the 20-30 and 30-40 m bottom depths, but not at the 0-20 and 40-80 m bottom depths (bottom depths beyond 80 m were not surveyed at all transects, and were therefore not included in the analysis). Visual examination of the data confirmed that the differences between ports were small and overshadowed by the variability between transects. Differences between bottom depth zones along the same transect were not addressed, since the transect density profiles (Fig. 5) indicated beyond doubt that there are identifiable patterns of distribution.

Comparison with Midwater Trawls

Echo-integration estimates should ideally be used to compare acoustic and trawling results. They represent the total acoustic signal converted into fish densities using the results of dual-beam analysis. The dual-beam data alone account only for fish that were recognized as individual targets (not clumped), and could under-represent high fish densities or schooling species. Visual inspection of the relationship between dual-beam and echo-integration data from this survey, however, revealed the two statistics to be similar at all densities. Since there appeared to be no saturation, and the dual-beam data were collected during the trawling operations, they were used in the comparisons with trawling results. The comparisons were based on density estimates (#/m^3) from the two gears, and included correlations between trawls and acoustics from the same depth, and mean ratio of trawl density to acoustic density. To simulate the possible contamination of trawl catches with fish from layers crossed during retrieval, correlations were also made with an acoustic estimate created by com-

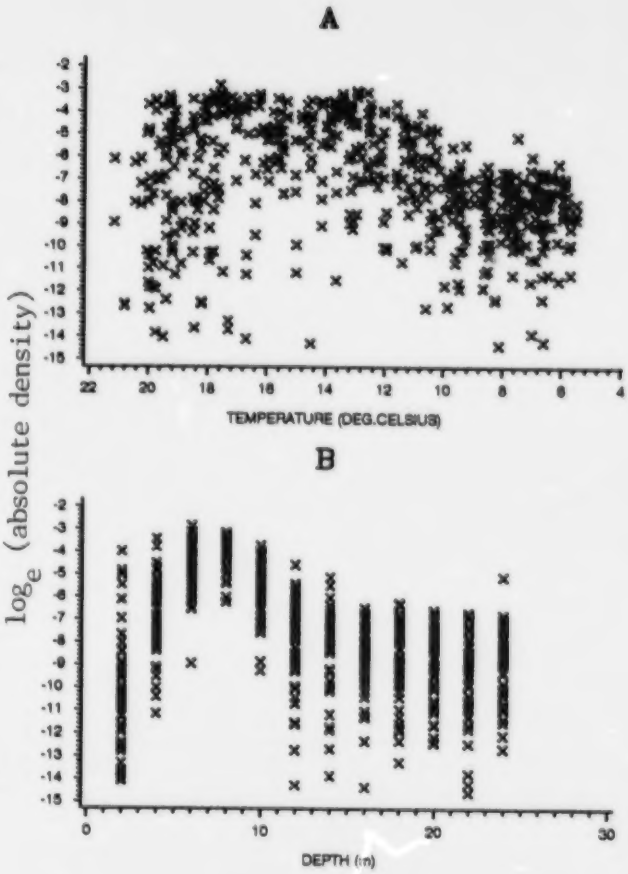

FIG. 3. Relationship between target densities and (A) temperature, (B) depth. Temperature data were collected during trawls, while hydroacoustic densities are means of three 1-min echo integration sequences, collected during the other leg of the transect at the same depth.

2 *There was often a mode in the distribution of target strengths that corresponded to YOY sizes, suggesting that YOY were sampled. At this time we cannot unequivocally say what these fish were (see discussion under Fish Sizes), and the point deserves further consideration.*

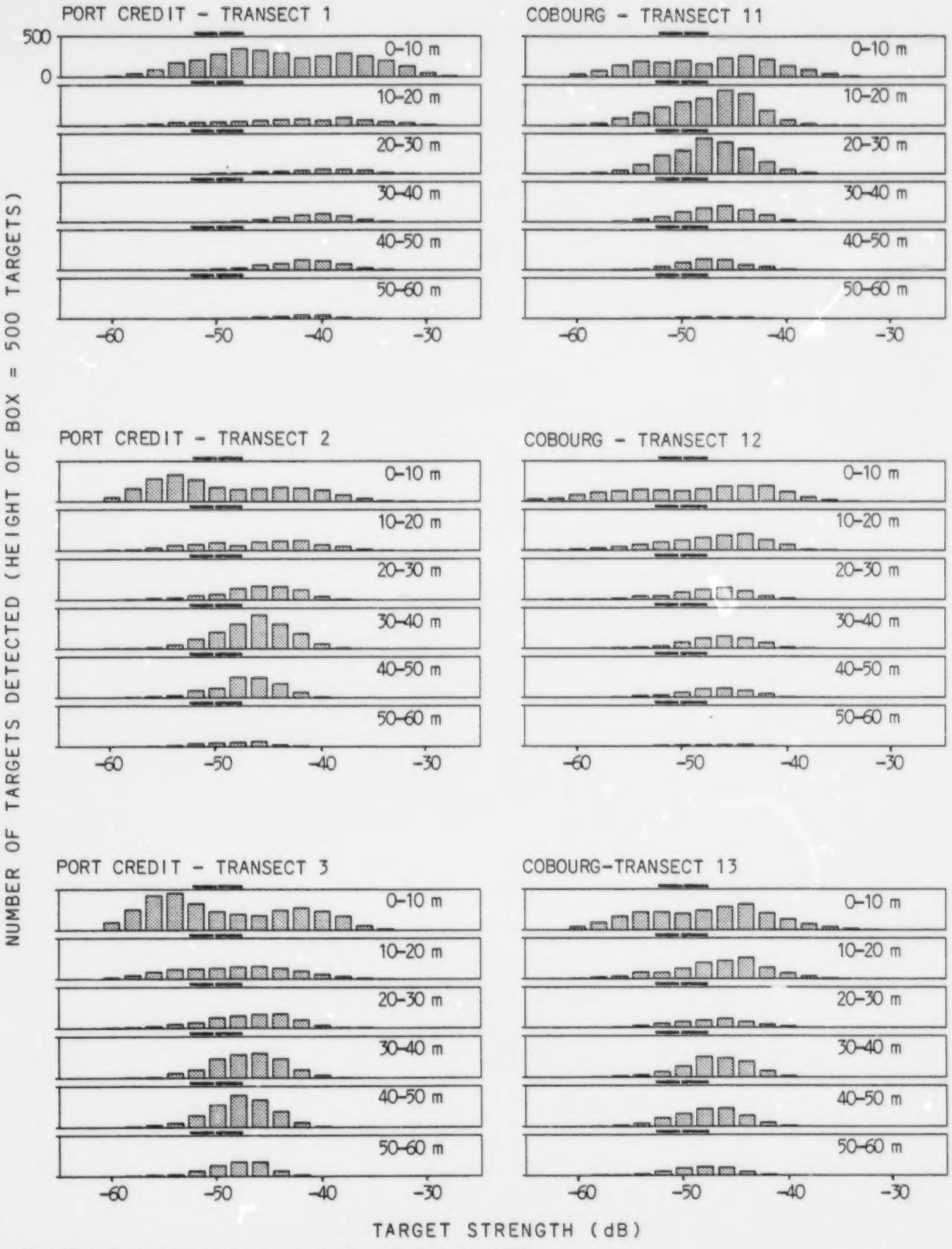

FIG. 4. Depth distribution and sizes of targets, data from dual beam, pooled by transect.

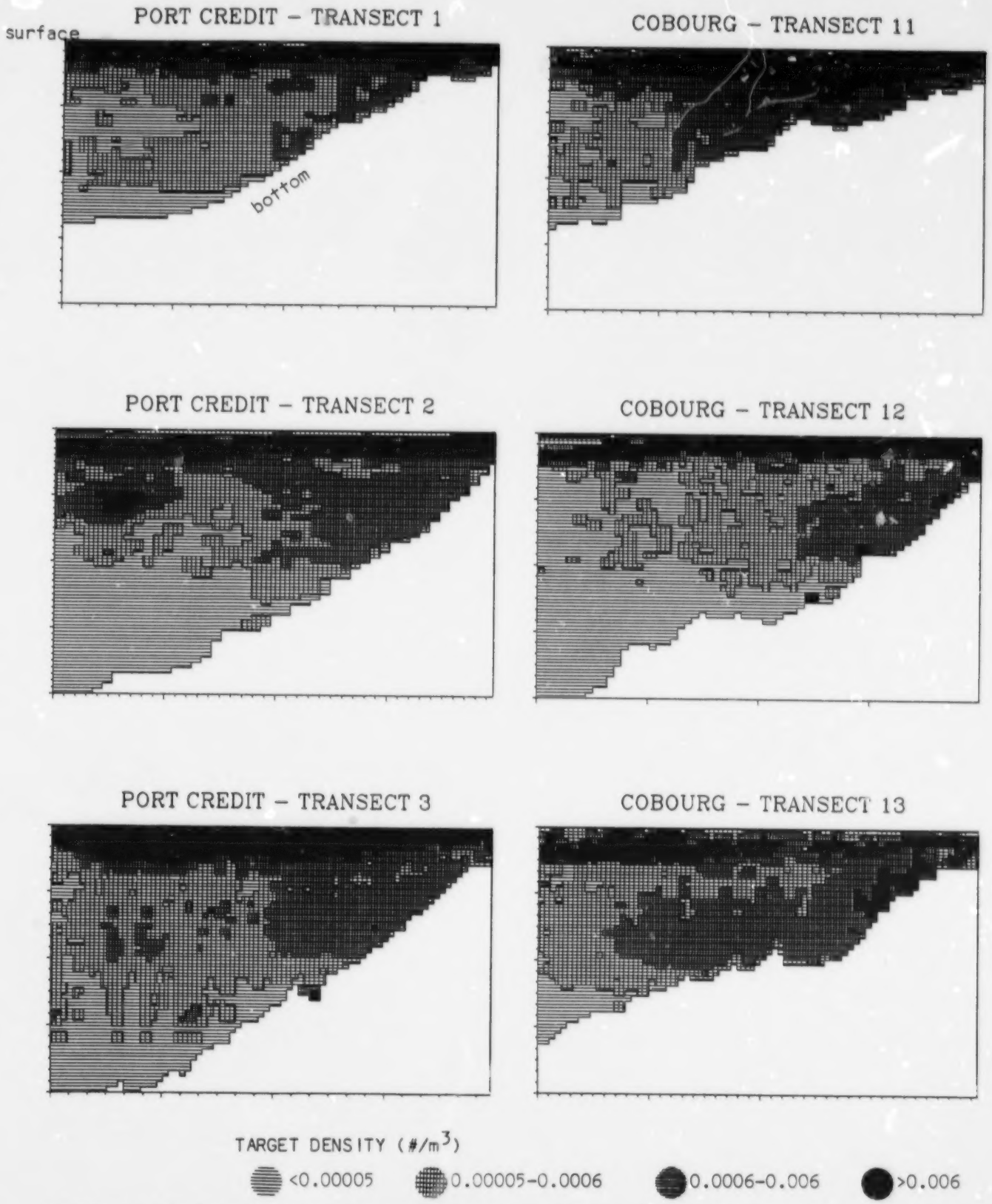

FIG. 5. Density profiles of the transects, as measured by the absolute density outputs from the echo integrator. Individual 1-min integrator outputs were averaged into 2-min segments for clearer picture, original 2 m depth categories were retained.

TABLE 1. Comparison between trawl and acoustics (dual beam) . Trawl density estimates (#/m^3) represent only the named species; they were calculated from net dimensions from net dimensions and towed distance, assuming 100% efficiency. Dual beam density estimates (#/m^3) included all target sizes. Two kinds of acoustic densities were used in correlation with trawls: 1) density from trawled depth only, and 2) density from trawled depth combined with 1/10 of the sum of densities in the water column above the trawled depth.

Species in trawl	Zone	Correlation between trawl densities and acoustic densities from: Trawled depth	Trawled depth and above	Mean value of ratio of densities (trawl over acoustics)
Alewife	Epilimnion	0.98**	0.98**	0.04
	Metalimnion	0.37	0.36	0.31
	Hypolimnion	0.65	0.86*	0.11
Smelt	Epilimnion	0.05	0.06	0.07
	Metalimnion	-0.09	-0.05	1.14
	Hypolimnion	-0.33	-0.62	3.35

[a] Pearson correlation coefficient, $\log_e$ transformed data * $p < 0.05$ ** $p < 0.01$

bining acoustic densities from the trawled depth with 1/10 of the summed acoustic densities from the overlaying depths. This fraction approximates the portion of a 20-min tow spent in deployment and retrieval of the gear.

Trawl catches of alewife in the epilimnion were strongly correlated with the acoustic estimates from corresponding depths (Table 1). The mean ratio of trawling to acoustic density estimates in this zone was 0.04. In meta- and hypolimnion, the correlations between trawl and acoustics from the same depth were not significant. In the hypolimnion, the correlation became significant when the combined acoustic density estimates were used (trawled depth plus depths above), suggesting contamination of trawl catches with fish from shallower water. The ratios of trawl densities to acoustic densities in meta- and hypolimnion were higher than in the epilimnion, but less than 1.0.

Trawl catches of smelt were not significantly correlated with either of the two acoustic estimates at any depth. In the epilimnion, the mean ratio of trawl to acoustic density was low, while in meta- and hypolimnion the mean ratios were higher than 1.0.

These observations are difficult to reconcile. High correlations with alewife estimates in the epilimnion suggest that alewife predominate this zone, but the low ratio of trawl to acoustic densities suggests that they are not caught efficiently by the trawl. This concentration of alewife may be the reason why the alewife correlations in the hypolimnion improve when combined acoustic estimates (trawled depth plus above) are used - the trawls are contaminated while crossing this layer. The alewife in deeper layers appear to be caught more efficiently, since the ratios of alewife to acoustic densities are higher, despite the fact that higher portion of the acoustic density is presumably due to smelt. The low alewife trawling efficiency in the epilimnion may be due to boat avoidance, and a similar avoidance could exist in smelt, though it cannot be discerned in the data. High trawl/acoustics ratios for smelt in meta- and hypolimnion suggest high trawling efficiency.

TABLE 2. Estimate of the total target population in the Canadian western basin of Lake Ontario.

Depth (m)	Area (ha)	Target density (#/m^3)	Estimated no. targets (millions)
Port Credit			
0-20	47164	0.119	56.0
20-30	17957	0.165	29.7
30-40	15327	0.128	19.6
40-80	68335	0.110	75.2
80+	135291	0.161	218.3
			Total: 398.8
Cobourg			
0-20	36100	0.146	52.8
20-30	18388	0.283	52.1
30-40	17740	0.423	75.1
40-80	101648	0.111	113.1
80+	167832	0.076	126.9
			Total: 420.0
			Overall total: 818.8

Population Estimates

The total target population for the Canadian waters of Lake Ontario west of Scotch Bonnet sill was estimated at 819 million, with 95% confidence interval of +/- 140 million (Table 2). Most of the targets, 93% or 762 million, were of size corresponding to alewife and smelt. This is 1.6 times more than the combined number of alewife and

smelt estimated for the same area in the midwater trawling survey (Mathers et al. 1991).

Partitioning the total number of targets into separate estimates for alewife and smelt critically depends on assumptions about the ground-truthing gear. Evidence from acoustics suggested that smelt were efficiently caught by the trawl at depths where they were most abundant; assuming accordingly that the trawling estimate for smelt (384 million) was correct, there were 378 million targets left to be assigned to alewife. This is 4 times higher than the alewife trawl estimate. Alternately, assuming that the trawling efficiencies for smelt and alewife were in the ratio of 1:1 (though both efficiencies low in the epilimnion), resulted in two estimates: 181 million alewife and 581 million smelt, when the calculations are stratified by limnological zone, or 144 million alewife and 618 million smelt when only the overall proportions from trawl are applied. All four estimates are 1.5 to 2 times the corresponding estimate from midwater trawl. Comparisons to spring bottom trawling estimates (Mathers 1991) can be made only in the western corner of the lake between Niagara and Toronto. Here the bottom trawl estimate of the total smelt population, excluding YOY, is 305 million fish. The corresponding acoustic *total* target estimate is 249 million fish. Regardless of how this number is partitioned, the smelt estimate from acoustics would be lower than the bottom trawling estimate.

Discussion

The acoustic estimate of the total number of targets in the Canadian western basin is almost twice the sum of alewife and smelt estimates from midwater trawl. This agrees with the finding (Mathers et al. 1991) that the midwater trawl underestimates the density of both species. Partitioning the acoustic results into alewife and smelt abundance estimates, requires that the trawling data be used to indicate the proportions. Several ways to partition the data were shown here, leading to different estimates. The estimates should be considered as tentative until ground-truthing problems are resolved.

Three ground-truthing problems were revealed in this survey:

1)The trawl efficiency near surface is low. The data indicate, that the trawl captures approximately 4% of the alewife in its path. This conclusion is based on the assumption that alewife dominate this layer, which in turn is based on the strong correlation between alewife in trawl and acoustics. Yet the catches of smelt in the same trawls actually exceeded those of alewife, suggesting a higher efficiency for smelt. Thus the efficiencies near surface may not only be low, but also different for the two species. To solve this problem will require further investigation. Trawling techniques that take the net away from the path of the boat (e.g. paired boat trawling) would eliminate boat avoidance, and use of larger net may decrease efficiency differences between alewife and smelt by decreasing the chances for escape. Alternately, correction factors could be established to compensate for different efficiencies.

2)Deep-water catches are contaminated with fish from shallower depths. The current data present some evidence of contamination, by showing that correlations between acoustics, and alewife from hypolimnetic trawls, improve when a measure of fish densities from shallower water is included. The problem of contamination can only be solved by closing the trawls during deplyment and retrieval.

3)Smelt catches in the trawls are not correlated with acoustics. It is puzzling, and the most plausible explanation is that the smelt distribution is patchy, leading to high variance of trawl catches, and obscuring the correlation. In that case, the consequence to ground-truthing would be that the number, duration or size of trawls must be increased to confidently estimate the proportion of smelt.

Interpreting all inconsistencies between acoustics and midwater trawl in terms of shortcomings of the trawl, implies that the acoustic data are without problems. This may not entirely be the case, however, some of the points made about the midwater trawl are either supported by other observations (trawl contamination, Schaner et al. 1990), or have been suspected before (inefficiency near surface). If these problems are serious, they will not only affect the ground-truthing function of the trawl, but also corrupt abundance estimates based on trawl only.

The hydroacoustic technique and interpretation of the data also needs further attention. At the time of writing we could not reconcile the interpretation of small targets that may correspond to YOY fish. Settling this pont may require species-specific equations to convert target strengths to fish sizes. The depth distribution of YOY fish suggests the use of upward-looking transducers to collect data near surface, or scheduling of the survey at times when the fish are found deeper.

The variance estimates and confidence intervals reported here are favourable, due partly to the large volumes of water examined by acoustics. The variances, however, were underestimated, because errors due to variability in the dual-beam data were not included. Future analyses should account for this error component. It can be minimized in the survey design by estimating echo integrator scaling factors at frequent intervals rather than using a single pooled value for an entire transect.

Temperature data were collected infrequently, mainly because of time constraints. More intensive temperature monitoring should be considered in future surveys, since stratification of the survey in terms of temperatures, rather than limnological zones may ease the interpretation problems. Better temperature data may also provide the link needed to apply findings from the current study of temperature zones (Stewart 1991) to acoustic results.

Acknowledgments

Canadian BioSonics, LTD., BioSonics Inc., and Bob Johnson in particular, were helpful and friendly beyond the terms of their contract. The LOFU operations staff worked long and odd hours to complete the survey. Steve Kerr provided helpful editorial comments. Thanks to Linda Balsillie for desk-top publishing and Carol Ward for copy-editing the manuscript.

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APPENDIX A

Summary of Hydroacoustic Methods and Terms

Hydroacoustic techniques rely on the same physical principles, and use similar technology as commercially available fish finders, but they add multiple transducers, sensitive calibration, and computer processing of the signal, to extract more information from the echo returns. Two processes are combined to estimate fish densities in the water column:

The **dual beam** technique uses two concentrically mounted transducers that have different off-axis sensitivity patterns. An echo from a target will therefore result in different signal strengths on the two transducers, and their ratio can be used to determine the off-axis angle of the target. Knowing the angle, and the sensitivity pattern on either of the transducers, allows determining what the signal strength would have been if the target had been on axis. A second type of compensation is necessary to account for the decay of acoustic energy in the water column. The amount of compensation depends on the distance of the target from the transducer, which can be determined from the time delay between firing of the pulse and reception of the echo. After compensation for off-axis position, and for distance from transducer, the signal provides a direct measure of the target's acoustic size - the **target strength**. The dual beam process compiles a sample of targets with measurements of their strength and position in the water column. Only single targets are included, while overlapping echoes arriving nearly simultaneously from two or more targets are rejected.

The second technique, the **echo integration**, uses a single transducer to measure the total energy reflected from all targets in the water column. The time delay in reception of the echo is used to categorize the energy by depth layers.

The results from the two techniques are then combined: the total acoustic energy from echo integration is multiplied by the **echo integrator scaling factor**, resulting in an estimate of fish density. The scaling factor accounts for the average acoustic size of the targets measured by the dual beam, as well as for equipment characteristics. The calculations are normally stratified by depth, combining depth-specific echo integrator output with depth-specific scaling factor to yield a depth-specific target density estimate.

All outputs from hydroacoustics are expressed in terms of target strengths. These are related to the physical size of the fish, with the relationship depending on the fish's shape, anatomy, and angle of orientation. The universal **Love's equation** (Love 1971) is often used as an approximation of this relationship applicable to all species.

Surveillance Report for Lake Trout Rehabilitation in Lake Ontario, 1990

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Lake Ontario Fisheries Unit 1990 Annual Report, LOA 91.1 (Chapter 16)

Progress towards rehabilitation of lake trout in Lake Ontario is described with reference to the terms of the 1983 rehabilitation plan. Stocking of lake trout has declined in 1990, and survival during the first year in the lake continues to decline, probably due to predation by adults. Adult survival has declined, reversing a recent trend. Mean age of adult females and age of first maturity have both increased, resulting in a slight decrease in the spawning index. Lamprey mortality has increased, as demonstrated by carcass densities and wounding rates. Angling harvests have increased. Growth and condition factor remain stable. Large numbers of wild fry were captured at the Stony Island reef, and Seneca strain eggs and fry continue to be the most common. One fry was captured at Yorkshire Bar, and eggs collected there come from all four strains commonly stocked in the lake. Three juvenile/adult fish were considered to be naturally produced.

Introduction

Reconstruction of a naturally reproducing population of lake trout is the focus of a major international rehabilitation effort in Lake Ontario. Coordinated through the Lake Ontario Committee of the Great Lakes Fishery Commission, representatives from many cooperating agencies developed a *Joint Plan for the Rehabilitation of Lake Trout in Lake Ontario* (Schneider, Kolenosky and Goldthwaite 1983), which identified a goal, an interim objective and several strategies for their achievement. The following report is organized along the same lines as the Joint Plan, with the intention to describe progress toward planned objectives. Assessment and monitoring methods have been described in detail in earlier reports; any readers interested in more information should review the appendices in the 1986 Surveillance Report (Schneider et al. 1987).

Strategy 1. Stocking

Since native stocks of lake trout in Lake Ontario are extinct, the major focus of our rehabilitation effort is the establishment of a new Lake Ontario strain(s). This entails rearing and introducing 2.5 million yearlings of various genetic stocks (1.25 million per nation), assessing strain performance, and emphasizing the use of progeny of lake trout that survived to maturity in Lake Ontario.

Numbers of lake trout stocked in 1990 declined by 7.6% (Fig. 1A). U.S. stocking increased slightly to 888,400, while Canadian stockings decreased 15%. The same five genetic strains were stocked in 1990 as 1989, but relative compostition changed (Fig. 1B). The proportion of Killalas diminished in 1990, although, they still represented the largest genetic component. Due to broodstock management and disease problems within Great Lakes lake trout hatcheries, numbers of Superiors also declined in 1990. The relative contribution of Manitou, Seneca and Ontario strains increased in 1990. Recently, stocking has stabilized near 1 million yearling equivalents for each nation.

Strategy 2. Maximize Recruitment of Stocked Fish

The Joint Plan recommends maximizing recruitment of stocked lake trout by optimizing hatchery rearing practices and stocking techniques. The use of coded wire tags for marking fish has made it possible to initiate studies to evaluate the effects of rearing density, time of planting, and stocking method on post-stocking survival.

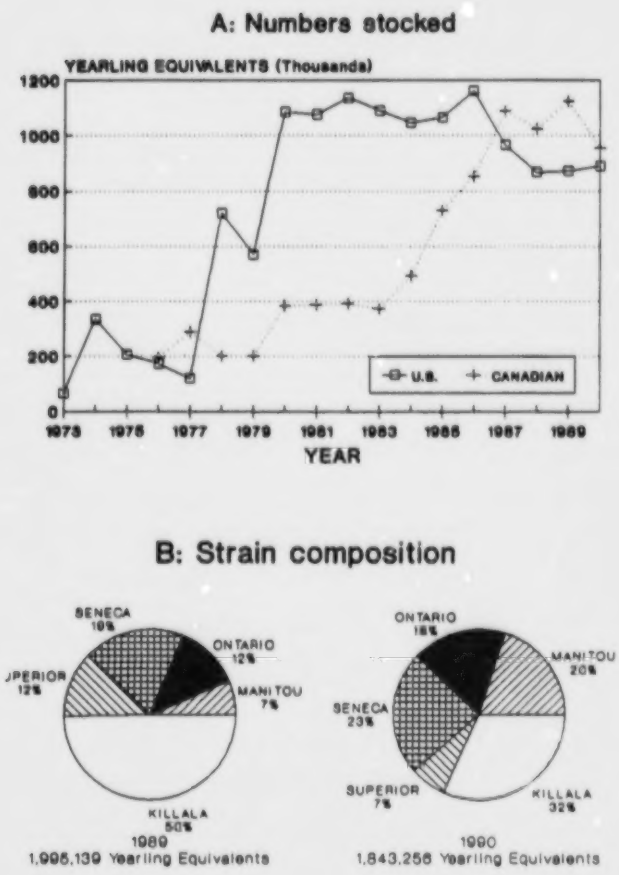


FIG. 1. Lake trout stocking. (A) Total numbers stocked in Canadian and U.S. waters. (B) Overall strain composition.

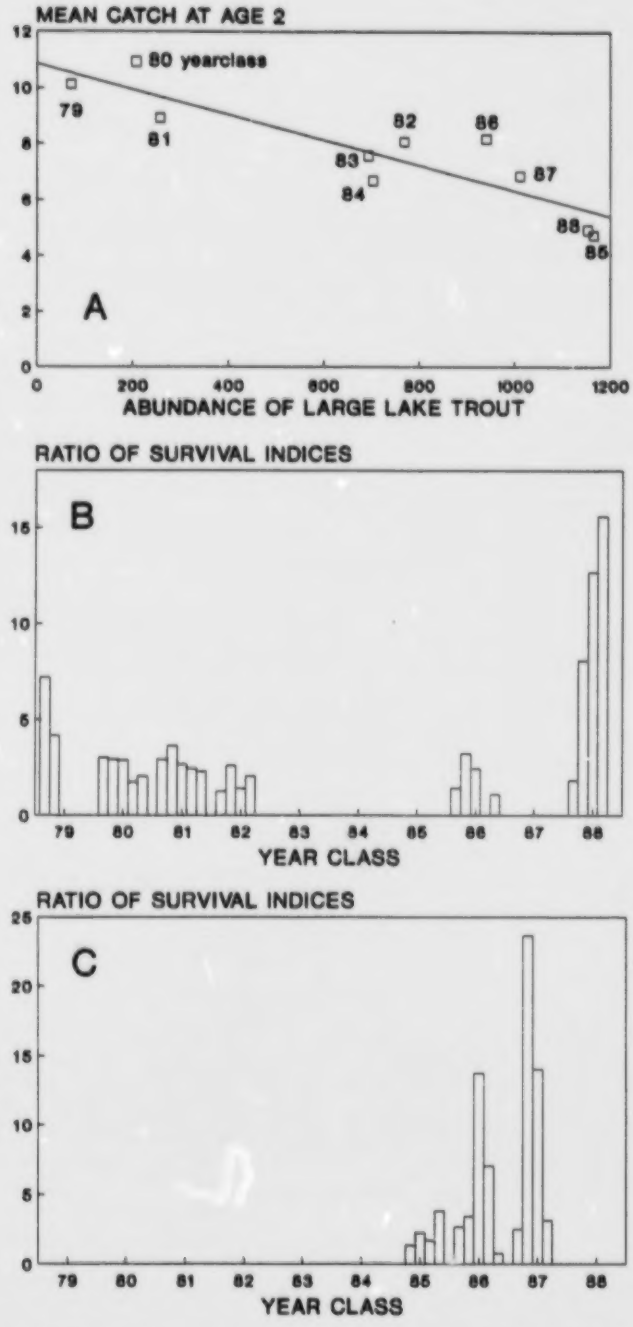


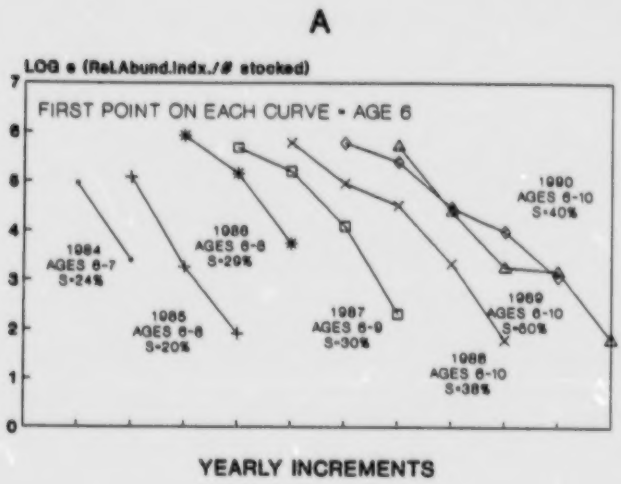
FIG. 2. Recruitment of stocked fish. (A) Relationship between survival of young Superior strain fish (mean trawl catch of 2-yr olds per 10,000 stocked) versus abundance during the year of stocking of fish larger than 530 mm. Numbers in the graph indicate year-class. (B,C) Number of fall fingerlings equivalent to one spring yearling, based on trawl catches of 2-yr olds adjusted for number stocked; each bar represents a paired stocking of fall fingerlings and spring yearlings at the same location: (B) Superior strain, (C) Seneca strain.

Catches of age 2 lake trout from the midsummer trawl survey indicated that survival during the first year following stocking declined by 40% in the 1980's for Lake Superior strain fish stocked as yearlings. Recruitment to age 2 was negatively correlated with abundance of large lake trout ($P < 0.01$, $r = -0.89$, Fig. 2A). At the same time, the contribution to the population from fish stocked as fall fingerlings also declined. In the early 1980's, we found that stocking 2.4 fall fingerlings was the equivalent of stocking one yearling. In recent years, however, this ratio has become more variable and larger numbers of fingerlings must be stocked to be equivalent to one yearling for both the Lake Superior and Seneca Lake strains (Fig. 2B, 2C).

Throughout the 1980's, when abundance of adult lake trout was increasing, the survival indices (SI) of young lake trout in U.S. waters based on gill net catches, diminished. During 1982 and 1990, the SI's decreased significantly for age 2 (59%, $P < 0.001$) and age 3 (63%, $P < 0.05$) lake trout. Moreover, this occurred at a time when size-at-stocking increased, thus minimizing the full impact of reduced survival. The most likely reason for these declines is predation by larger lake trout.

Strategy 3. Maintain Adult Survival between 60 and 65%

Successful rehabilitation of lake trout in Lake Ontario demands that enough planted fish survive to produce a



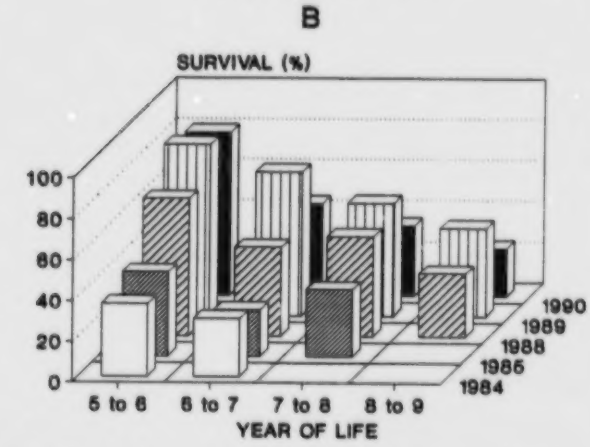


FIG. 3. Survival of adult lake trout. (A) Catch curves from selected years 1984 to 1990, based on relative abundance indices adjusted for number stocked. (B) Age-specific survival rates from selected years; survival at age 5 means survival from ages 5 to 6.

viable spawning stock. The Joint Plan prescribes a survival rate of 60 to 65% per year. To attain this level, the plan further suggests that lake trout deaths from sea lamprey should be minimized and exploitation by the fishery should be limited.

Survival of Adults

During 1990, survival of adult lake trout in U.S. waters declined[1]; this marks a reversal of the recent trend of continually improving survival. Two methods were used to examine survival and both indicated a decline. Based on catch curve analysis, survival of lake trout older than age 6 steadily improved, from 20% in 1985 to 50% in 1989 (Fig. 3A). In 1990, however, survival decreased to 40% (95% confidence limits 29 to 60%).

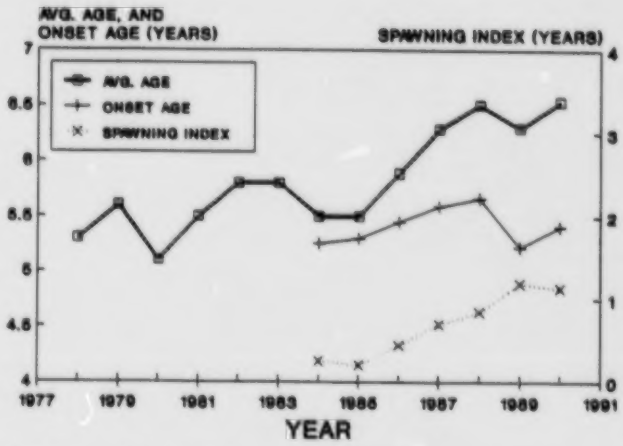


FIG. 4. Maturity statistics for female lake trout. Average age is the mean age of mature females. Onset age was calculated by the method of Abrosov (1969). Spawning index is the difference between the two ages.

Survival of adult lake trout was also estimated from gill net abundance indices of individual year-classes at successive ages. This method is more sensitive to annual changes in survival, but in some years, results can be erroneous, because of variations in catchability (e.g. 1986 and 1987). From 1989 to 1990, survival of all age groups of adults declined: age 6-7, 71 to 45%, age 7-8, 55 to 35%, and age 8-9, 43 to 24% (Fig. 3B). Changes in catchability did not appear to adversely affect these estimates, since relative abundance of younger fish was comparable to other years and because of the agreement with catch curve estimates.

Continued high mortality of older age-classes indicates that older lake trout do not survive as well as younger individuals. Since both fishermen and sea lamprey actively seek the largest lake trout in the population, an increase in lake trout mortality is expected.

Average Age of Mature Females

One of the objectives of the rehabilitation program is to re-establish a suitably-sized spawning stock that encompasses several year-classes. The average age of mature females was selected as an index of age composition. Older average ages indicate populations with more age groups and older fish. The current objective for average age is 7.5 yr.

The average age of mature females taken in gill nets in U.S. waters in 1990 improved to 6.5 yr (Fig. 4). At the same time, onset of maturity, the average age of first maturity, increased to 5.4 yr. The difference in these two averages - the spawning index - declined. This suggests that the improvement noted in average age of mature females was attributable to fewer young adults and not because more females were surviving to older ages. These measures of maturity are consistent with the conclusion that survival declined.

1 *U. S. data was used for estimating survival because the long-term use of coded wire tags permitted accurate aging of most adults.*

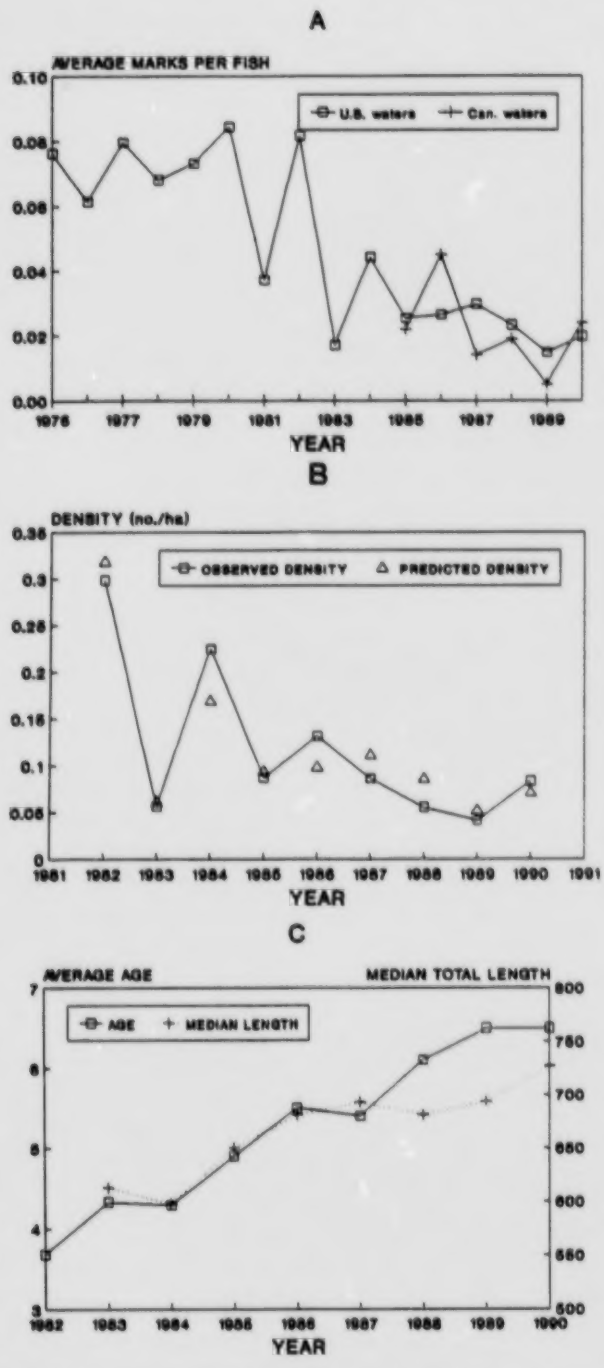


FIG. 5. Lamprey wounding and mortality. (A) Marking rates (A1 wounds only). (B) Carcass densities in U.S. waters; predicted densities were calculated from the relationship between observed carcass densities and A1 wounding rates: density = 4.018(wounding)-0.0096, r = 0.964. (C) Size and age of lake trout carcasses from U.S. waters.

Strategy 3.1. Minimize Losses from Sea Lamprey

Three basic approaches were outlined to minimize sea lamprey predation. First, and foremost, was to maintain adequate control of sea lamprey recruitment through the use of chemicals, barrier dams and/or other means. Secondly, increasing prey biomass should ultimately lead to reduced mortality of lake trout, since sea lamprey, under conditions of high density of large prey, are thought to function more like parasites than predators. The third tactic outlined in the plan was to stock genotypes of lake trout that were potentially resistant to sea lamprey induced mortality.

Monitor Sea Lamprey Impacts

In Lake Ontario, a close association exists between sea lamprey marking rates (stage A1) and lamprey-induced mortality of lake trout ($P < 0.001$, $r = 0.946$). Between 1989 and 1990, September marking rates increased 33%, from 0.0148 to 0.0197 marks/fish (Fig. 5A). This rise reversed a two year decline, but the marking rate in 1990 was still among the lowest observed. Because of the excellent correspondence between A1 marking rates and fall mortality of lake trout, the increase in marking suggested that sea lamprey predation on lake trout would expand in the fall of 1990.

Lake trout carcasses have been collected with bottom trawls in U.S. waters[2] each fall, since 1982. Results from these surveys provide direct and current evidence of sea lamprey induced mortality on lake trout. Total area swept by the trawls each fall ranged from 40 ha in 1982 to 485 ha in 1985. Relatively few carcasses were recovered each fall; the least was 7 in 1983 and the most was 42 in 1985. In 1990, 18 carcasses were recovered from 270 ha of lake bottom.

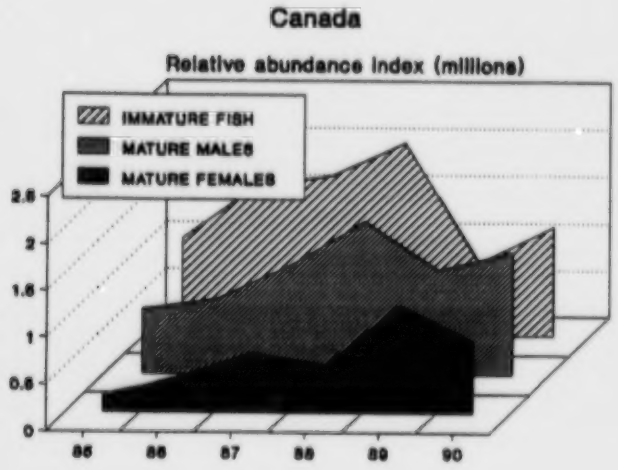
Carcass density in the 30-99 m depth stratum is the longest and most complete series (Fig. 5B). As expected, density of lake trout killed in 1990 by sea lamprey more than doubled (0.041 in 1989; 0.083 in 1990). This level of mortality was comparable to that observed during 1985 and 1987, and was very close to that predicted from marking rates. It is important to note that this increase in lake trout mortality will continue to be reflected in the aforementioned survival rates. Because survival is based on September-to-September estimates of lake trout abundance, the higher mortality due to sea lamprey in the fall of 1990 suggests that survival in 1991 will not improve, and may decline even further.

As carcass density declined from 1982 to 1989, the average age and size of carcasses increased (Fig. 5C). Although, sea lamprey predation on lake trout increased in 1990, carcass average age remained unchanged and median length increased; suggesting that sea lamprey continue to select the largest hosts available.

Increase Prey Biomass

The number of mature lake trout in Lake Ontario has risen substantially throughout the 1980's, but in 1990 the numbers fell (Fig. 6). In Canadian waters, relative abun-

2 *The lake bottom in U.S. waters is smoother and less obstructed than that on the Canadian side, which makes this type of effort-intensive sampling possible.*



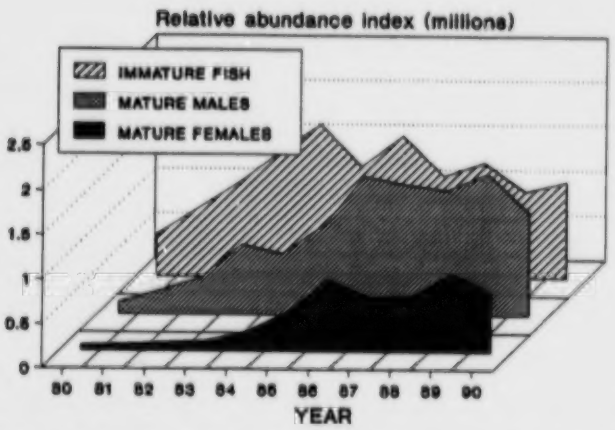


FIG. 6. Relative abundance indices in Canadian and U.S. waters. The indices are calculated as weighted sums of caught lake trout, with stratum area (hectares) as the weighting factor.

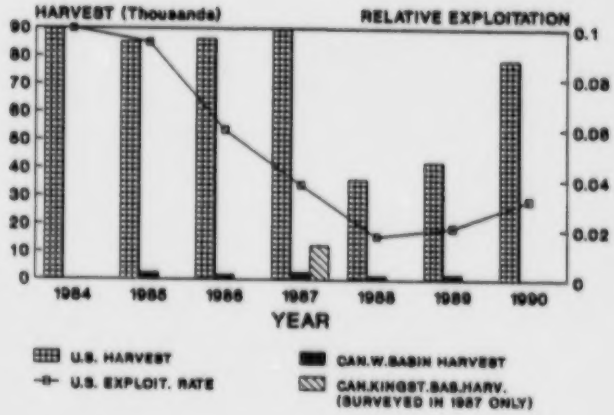


FIG. 7. Lake trout harvest and relative exploitation rate (ratio of harvest to relative abundance index).

dance of mature lake trout declined by 9% (both sexes combined), with females reduced by 33% while males increased by 17 percent. In U.S. waters, there were fewer spawners of both sexes; with a 23% and 28% decline for females and males, respectively.

Strategy 3.2. Limit Exploitation:

Fishing is the other major, controllable component of lake trout mortality in Lake Ontario. Creel surveys provide an effective and reliable means for quantifying the number of lake trout killed by anglers. This information, in conjunction with carcass survey estimates, should permit a reasonable assessment of the corrective actions necessary to improve survival.

Canadian and U.S. creel surveys do not sample all fisheries. The last Canadian survey in the central and Kingston basin occured in 1987, and will not be repeated until 1992. The U.S. surveys did not census the Kingston Basin either, although a comprehensive survey in 1984 suggested that U.S. estimates for 1985 to 1990 probably represented about 85% of the actual harvest.

The 1990 estimate of lake trout harvest by sport fishermen in the Canadian western basin is not known at the time of writing, but anticipated to be similar to the low 1989 levels (Fig. 7). The 1990 harvest in the central and Kingston basin is not known; the 1987 harvest estimate for the Kingston basin was 12,202 lake trout (Mathers 1988), and the fishery appears to be growing.

The U.S. sport harvest of lake trout in 1990 was 78,786, representing an increase of 87% over the previous year. In the years 1984-87, the harvest in U.S. waters was stable at approximately 85,000 fish. To reduce fishing mortality, and to enhance rehabilitation, on October 1, 1987, DEC instituted a slot limit protecting lake trout between 625 and 762 mm (25 to 30 in). Because the harvest subsequently fell below the planned target of 60,000 fish, harvest restrictions were liberalized in July 1989 by narrowing the slot to 686 to 762 mm (27 to 30 in). Year 1990 was the first full year of the liberalized slot limit, and the 1990 harvest again exceeded the planned target of 60,000 fish by 55%.

Undoubtedly, this expansion of harvest contributed to the reduction in numbers of spawners, and to the decline observed in survival rates. Because the abundance of adult lake trout decreased as harvest expanded, relative exploitation (harvest/relative abundance) rose by 53%, reversing, unfortunately, an important trend toward diminished exploitation (Fig. 7).

Strategy 4. Maximize Reproductive Potential

In the Joint Plan, degradation of the ecosystem was not considered a causal agent in the demise of native lake trout, principally because lake trout were declining prior to the period of most intensive eutrophication and contamination. However, habitat quality is now diminished and may hinder rehabilitation. The suggested approach to maximizing reproductive potential of the new Lake Ontario stock involves: (1) improving water and habitat quality, (2) maximizing use of the least degraded spawning

TABLE 1. Lake trout fry catch rates at Stony Island during the spring 1990.

Date	Number of traps	Number of fry	Fry per trap day	% emergent fry
Apr-12	62	-		
Apr-16	62	7	0.028	0
Apr-23	62	113	0.26	0
Apr-30	62	306	0.705	0.3
May-07	62	75	0.173	6.7
May-14	62	21	0.048	61.9
May-22	62	2	0.004	100
May-28	62	0	0	-

and nursery habitat, and (3) determining those conditions on the spawning grounds which may be inhibiting successful reproduction.

Fry-Trapping

Sixty emergent fry traps were deployed on an area approximately 50 x 10 m at the Stony Island reef from April 12 to May 28, 1990. A total of 534 fry were collected (Table 1). At Yorkshire Bar, 99 traps were set on the shoal on April 23, 1990. Traps were inspected five times during May 1-31, and one fry was collected (Casselman 1991).

All fry captured at Stony Island were transported to Cornell University for parental strain analysis. Fry were analyzed for both allozyme and mtDNA markers. Naturally deposited eggs, collected by divers in the fall of 1989 from Stony Island and Yorkshire Bar, were reared to swim up fry, and examined for allozyme and mtDNA markers. Data from both, wild fry and naturally deposited eggs, were consistent with results obtained in 1986, 1988, and 1989, when more than 60 percent of fry were of Seneca origin (Table 2,3). At Yorkshire Bar, Killalla, Manitou, Seneca, and Superior strains contributed relatively similar proportions (30, 32, 12, and 24% respectively, Table 3).

Alewife Abundance vs. Lake Trout Fry Capture

Two gangs of monofilament gill nets were placed on Stony Island reef adjacent to the location where lake trout fry were captured. Sampling began on April 16 and terminated on June 11. On each of eight sampling dates, 1-hr sets of each gang were made approximately one hour before sunset and at sunset. Alewife catches increased over the month of May and then declined in June. The first alewives were captured on May 7 (32 fish), just after fry catches peaked on April 30. The last fry were collected on May 22. More than 95% of alewives had food in their stomachs. Amphipods were the most common food; no lake trout fry were observed. These data document that alewife were present and actively feeding at the same time and location as lake trout fry.

Fall Egg Collections

Egg Traps and Bags

In addition to egg traps, new collecting devices, egg bags, were used on Stony Island reef and adjacent artificial rock piles in the fall of 1990. The bags consisted of a 32 cm diameter ring with a 90 cm deep mesh bag attached (surface area 0.08 m^2). The bags were placed in a hole, the ring flush with the bottom, and filled with displaced substrate. Each bag had a single egg trap attached to the ring to assess trap effeciency. The attached traps were weighted with lead to reduce "flapping" in the current, and subsequent damage and loss of units.

Thirty bag/trap units were placed in three parallel transects along the slope of Stony Island reef in September 1990. Ten units were placed at each of three depths (4, 6, and 8 m). The units were retrieved November 30. Both egg bags and traps were effective in collecting eggs (Table 4). Egg traps near the bottom of the reef were usually filled with silt/sand/shells, which we suspect hampered trap efficiency. Debris had minimal effect on bag efficiency (one unit contained 1600 eggs in the bag and only a few eggs in the trap). This may explain why the bag/trap ratio for the transect near the bottom was about twice as high as other transects.

Mortality of eggs captured in these units increased with depth (Table 4). Since most spawning activity occurs on top of the reef, possibly eggs drifting down the slope are damaged. When diver's observed lake trout, they were usually near the top of the reef.

Sculpins captured in the bags (Table 4) provided estimates of sculpin density, size distribution, and egg predation. Fifty-three percent of sculpins were less than 50 mm, 26% were from 50 and 55 mm, and 21% were over 55 mm. No sculpins under 50 mm had eggs in their stomachs. Those between 50 and 55 mm averaged 0.1 eggs in their

TABLE 2. Locations and numbers of naturally produced fry and eggs which were analyzed for parental strain contributions.

Sample	Date	n	Comments	Location
Fry-86	Spring 86	75	Wild fry from fry traps	Stony Island
Fry-88	Spring 88	94	Wild fry from fry traps	Stony Island
Fry-89	Spring 89	129	Wild fry from fry traps	Stony Island
Fry-90	Spring 90	200	Wild fry from fry traps	Stony Island
York-90	Nov.27/89	100	Eggs from SCUBA dives	Yorkshire Bar
StonyDT-90	Dec.6/89	129	Eggs from SCUBA dives	Stony Island
StonyDT-90	Oct.30/89	30	Eggs from egg traps	Stony Island

TABLE 3. Estimates of the percentage of parental strains contributing to the wild lake trout fry and naturally deposited eggs collected from Stony Island and Yorkshire Bar. CWL = Clearwater Lake, JEN = Jenny Lake, KIL = Killala Lake, SEN = Seneca Lake and SUP = Lake Superior. For an explanation of sample abbreviations refer to Table 2.

SAMPLE	n	CWL	JEN	KIL	MAN	SEN	SUP
Fry-86	75	0	0	2	0	90	7
Fry-88	94	0	1	16	0	72	13
Fry-89	129	0	0	15	0	72	13
Fry-90	200	0	1	34	0	61	4
StonyDT-90(eggs)	156	1	0	10	5	72	12
York-90 (eggs)	100	1	1	30	32	12	24

TABLE 4. Egg collection data from three transects of eight bag/trap units. Units were placed on Stony Island reef in mid-September 1990 and removed November 30, 1990. (n = 8 per transect)

	Transect depth (m)	NO. EGGS mean	S.D.	range	Percent alive	No. sculpins
Bags	3.7	60	16	41-85	32	2
	5.5	37	17	14-70	28	2
	7.3	58	25	22-84	22	2
Traps	3.7	16	6	9-26	38	0
	5.5	7	2	4-11	27	0
	7.3	7	4	3-14	3	0
Bag/trap ratio	3.7	4	1	2.5-9.6	-	-
	5.5	5	2	2.8-10.0	-	-
	7.3	9	6	1.9-19.0	-	-

stomachs and sculpins over 55 mm had 1.3 eggs in their stomachs.

Artificial Rock Piles

Six piles (7x3x1 m) of cobble-sized rocks were placed about 100 m south-west of Stony Island reef on a sand-pebble-gravel substrate. Two piles were located at each of three depths (4, 6, and 10 m). The two piles at 6 m were located on the slope. A minimum of 15 m separated each pile. Egg traps and egg bags (not attached to each other) were placed on, and adjacent to, each rock pile. On average, 34 eggs were collected in the bags. Those on the two shallow rock piles collected fewer eggs than bags on deeper piles. Diver sightings of lake trout over the piles, and collected live eggs, suggests that lake trout spawned on the artificial substrates, but not on adjacent, natural substrates. However, some of the eggs captured may have drifted from the reef.

Egg Incubators

To compare the egg incubating quality of the rock pile substrates with natural substrates, incubators with 50 fertilized eggs each were buried in both substrates. Additional incubators were placed in the hatchery at Cornell University and used as controls. Gametes used in the incubators were from lake trout captured off Stony Island and incubators will be retrieved in the spring of 1991.

On Yorkshire Bar, 88 incubators containing Lake Manitou and Ontario[3] strain eggs were placed in the substrate. Controls were maintained at the Glenora Fisheries Station, and interchanges between the two sets of incubating eggs were made to examine the effects of time and duration of exposure at the natural substrate (Casselman 1991).

Natural Reproduction

Because all lake trout stocked in Lake Ontario were marked, by either fin-clipping or coded wire tagging, the frequency of occurrence of unmarked lake trout during trawl and gill net surveys is useful in establishing the extent of natural reproduction. All unmarked from these surveys were examined using the protocols established by J.M. Casselman, to determine whether they were naturally-produced or of hatchery origin. This examination included establishing the presence or absence of a coded wire tag, adipose and paired fins, and hatchery characteristics in the otoliths and scales.

Three lake trout collected during agency surveys in 1990 were considered naturally produced (Casselman 1991).

3 *Wild fish stripped and fertilized in vitro.*

Although these three fish demonstrate that natural reproduction is possible in Lake Ontario, the occurrence of wild lake trout in our collections remains low (less than 1%).

Density Dependent Effects

The Joint Plan recognized that density dependent responses could confound the attainment of plan objectives. The plan forecast that as the lake trout population expanded, growth rates would decline, age at maturity would increase, fecundity would be reduced, and natural mortality could increase. These kinds of changes were not intended to forebode a population collapse; instead, they are normal responses that should be expected as the population increases.

Growth

Lake trout condition declined significantly from 1978 to 1986, but remained fairly stable thereafter (Fig. 8B). Weight-length regressions, calculated from fish taken in September gill net surveys, were used to estimate condition by predicting the weight of a 600 mm fish. Predicted weight in 1990 was 2,106 g. The decline in condition was associated with an increase in adult abundance ($P < 0.001$, $r = 0.94$). Since 1986, adult abundance has remained stable (Fig. 6) and predicted weights have also stabilized.

Although the condition of lake trout was changing in response to density, there were no detectable trends in total lengths of lake trout over age 4 (Fig. 8A). Total lengths of most age-classes older than age 4 declined in 1990 from the unusually high levels observed in 1989, but were near the long-term average. From 1978 to 1990, there was a highly significant increase in the lengths of yearlings, presumably in response to improved cultural practices. Because size of yearlings increased over time, it was not unexpected that lengths of age 2 lake trout were also progressively larger ($P < 0.02$). The only significant decline in growth was observed for age 4 fish ($P < 0.02$).

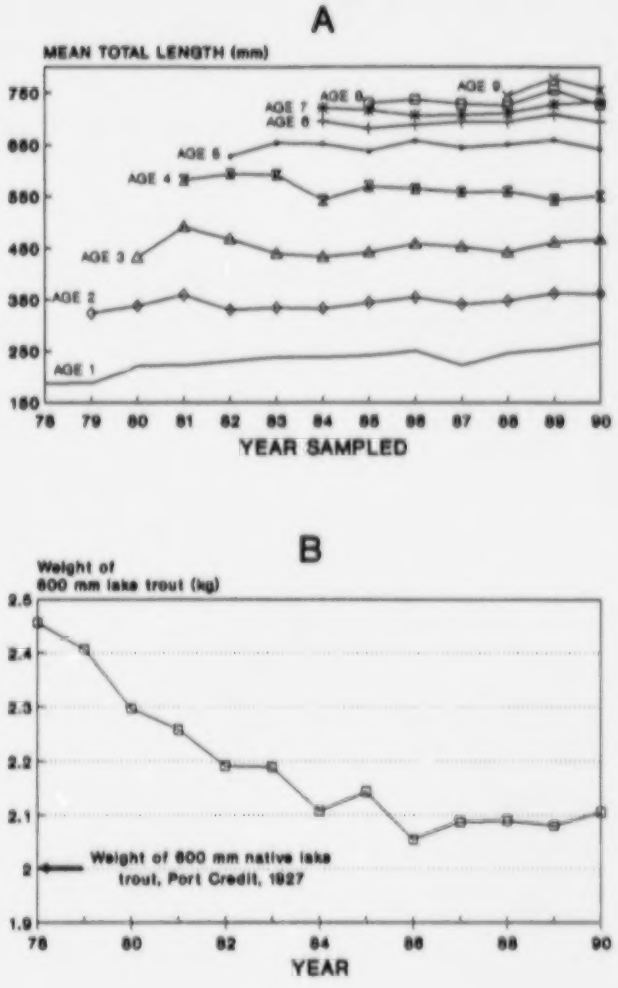


FIG. 8. Growth and condition of lake trout. (A) Length-at-age. (B) Weight og 600 mm lake trout calculated from yearly length-weight regressions. Historical data indicate that in 1927, a 600 mm lake trout weighed 2.0 kg.

Forecast

Because of the lack of progress towards our goal of lake trout rehabilitation during 1990 in U.S. waters, a forecast for 1991 may be helpful to guide resource managers in modifying existing tactics:

1. Losses of lake trout from sea lamprey predation almost doubled in the fall of 1990 and these losses will depress numbers of older, larger fish in 1991.

2 In U.S. waters, the relaxation of restrictions on angling harvest resulted in near doubling of harvest in 1990. Because of the historical consistency of lake trout harvest under the same angling regulations, harvest in 1991 will continue to exceed the target level of 60,000 fish. In Canadian waters, lake trout harvest should remain low.

3. Because of the known increased loss of lake trout due to lamprey predation, and because of the anticipated excessive loss from angling, survival of adults (ages 6-10) in U.S. waters will probably not improve in 1991, and may decline even further. Along with survival, the average age of mature females is also expected to decline. Survival of lake trout in Canadian waters should be better than in the U.S. waters.

4. Based on a lake trout assessment model for U.S. waters, the 1991 projected numbers of new adult recruits (age 5, 1986 year-class) should be near the short-term average. The model also predicts that overall abundance of adults (age 5 and older) will increase by about 10%, but adult numbers in 1991 will still remain below the peak observed in 1989.

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Lake Ontario Stocking and Marking Program for 1990

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Lake Ontario Fisheries Unit, 1990 Annual Report, LOA 91.1 (Chapter 17)

Introduction

The Lake Ontario fish stocking and marking program report is prepared annually as a joint New York State Department of Environmental Conservation (NYDEC) and Ontario Ministry of Natural Resources (OMNR) effort. The report is prepared to present numbers of fish stocked and identifying marks used on fish stocked into Lake Ontario by both agencies[1]. Tables 1 and 2 provide statistics on numbers of fish stocked in 1989 and 1990 and numbers of fish proposed for 1991 stocking. Tables 3 and 4 provide information on numbers of fish stocked into Lake Ontario from 1968 through 1990 by both agencies. Tables 5 and 6 provide detailed information about the areas of Lake Ontario that were stocked in 1990. In addition, these tables (5 and 6) contain species information including strain, hatchery or origin, size at stocking and marks. Table 7 identifies the deviations from the proposed 1990 stocking and explains the reasons for the changes.

The proposed stocking of trout and salmon by OMNR and NYDEC for 1991 is presented as numbers of fish by species, expected age of stocking, and proposed stocking sites in Tables 8 and 9.

Comparison of OMNR and NYDEC Lake Ontario stocking is shown as abundance of each species by percent in Fig. 1 and as actual numbers by age group in Fig. 2. The stocking trends by both agencies is shown in Fig. 3 and the trends by species of fish stocked by both agencies combined is depicted in Fig. 4.

Results

The 1990 Lake Ontario fish stocking by government agencies consisted only of salmon and trout. Private groups in New York raised and stocked walleye from fry provided by NYDEC from the Oneida Hatchery. The total number of salmon and trout stocked in all Lake Ontario waters combined was 7,715,143. The stocking of 2,233,543 salmonids in Province of Ontario waters was slightly below the number proposed for 1990 stocking. The New York stocking of 5,481,600 salmon and trout was slightly above the proposed target. The nearly 125,000 walleye stocked by private groups in New York was the highest since the program began in 1986.

The NYDEC stocking total increased by over 200,000 (4%) fish from 1989 to 1990. The positive aspects of the increase were the large increase of brown trout yearlings (nearly 54,000) and Washington steelhead (nearly 28,000 yearlings and 105,000 fingerlings). The lack of Skamania steelhead and reduced Atlantic salmon yearlings are considered to be short-term problems and are expected to be at least partially alleviated in 1991.

The numbers of lake trout and coho stocked by NYDEC needs some clarification. NYDEC lake trout stocking target is still over 1,000,000 yearlings, but only approximately 800,000 fish were produced in 1990. The excess number of fingerling lake trout stocked should partially compensate for the yearling shortfall. The NYDEC coho yearling decline is due to a policy change which calls for yearlings to be stocked for developing potential brood stock and all others to be stocked as fingerlings.

The OMNR stocking total dropped by almost 277,000 (11%) fish from 1989 to 1990. The OMNR stocking of coho salmon and Atlantic salmon exceeded proposed numbers. The numbers of chinook salmon, brown trout, lake trout and rainbow trout stocked by Ontario were below target. In February of 1991, OMNR announced the closure of three provincial fish culture stations and the discontinuation of the coho salmon stocking program. As a result of these actions, OMNR's Lake Ontario Management Committee will be reviewing stocking targets and priorities for 1992.

The 1990 stocking, by American and Canadian agencies combined, was about 310,000 (4%) fish below the proposed targets for 1990 and nearly 500,000 (6%) below the agreed 8.2 million (+/- 5%) stocking limit for Lake Ontario.

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1 *Most stocked fish are raised in Provincial fish culture stations or State fish hatcheries. Exceptions in 1990 included: lake trout provided by United States Fish and Wildlife Service from the Allegheny National Fish Hatchery. Private groups raised walleye fry provided by the NYDEC and stocked them as fingerlings.*

Terminology

Following are explanations for some of the terms and abbreviations used in the tables and graphs.

Steelhead: A migratory rainbow trout, technically, one which undergoes the parr-smolt transformation and migrates to Lake Ontario from the stream in which it was stocked, or hatched in the case of wild fish.

Domestic Rainbow trout: A rainbow trout that is not known to exhibit a parr-smolt transformation and, therefore, is stocked directly into the lake since it would not be expected to migrate to the lake if stocked in a stream.

Atlantic salmon: Includes the ocean run strain of fish generally referred to as Atlantic salmon and the lake dwelling strain called landlocked salmon.

Mark: Body part removed or tag added for identification

LV: Left ventral fin

Ad-LV: Adipose and left ventral fins

RV: Right ventral fin

Ad-LP: Adipose and left pectoral fins

LV-RV: Both ventral fins

RP: Right pectoral fin

LP: Left pectoral fin

LV-LM: Left ventral fin and left maxillary bone

CWT: Coded Wire Tag (60-42-14; the first two numbers are the agency code; i.e. 60, 23 and 63 are agency codes for FWS, NYDEC and OMNR respectively, the third through sixth numbers identify individual lots of fish)

Some graphs and tables use the following species name abbreviations:

Coho:	Coho salmon	Splk:	Splake
Chin:	Chinook salmon	Lake:	Lake trout
Atla:	Atlantic salmon	Brwn:	Brown trout
Rbow:	Rainbow trout	Brok:	Brook trout
Sthd:	Steelhead trout	Wall:	Walleye
Koka:	Kokanee	Salm:	Salmonid

TABLE 1. Salmon and trout stocked in Province of Ontario waters of Lake Ontario in 1989 and 1990 and proposed for 1991.

Species	Age	Number Stocked 1989	Number Stocked 1990	Number Proposed 1991
Brown Trout	Yearling	360,092	386,718	435,000
	Adult	275	0	0
	Total	360,367	386,718	435,000
Coho Salmon	Yearling	203,629	169,289	160,000
	Fingerling	87,024	65,575	80,000
	Total	290,653	234,864	240,000
Lake Trout	Yearling	1,124,039	948,574	1,150,000
Chinook Salmon	Fingerling	541,187	497,347	650,000
Rainbow Trout	Yearling	118,493	0	175,000
	Fingerling	0	104,994[a]	0
	Total	118,493	104,994	175,000
Atlantic Salmon	Yearling	60,782	27,446	50,000
	Fingerling	15,000	33,600[b]	0
	Total	75,782	61,046	50,000
	LAKE TOTAL	2,510,521	2,233,543	2,700,000

[a] 11 month old spring fingerlings
[b] 10 and 11 month old fingerlings, except for 1,600 six month old fish

TABLE 2. Salmon and trout stocked in New York waters of Lake Ontario in 1989, and 1990 and proposed for 1991.

Species	Age	Number Stocked 1989[a]	Number Stocked 1990[a]	Number Proposed 1991
Brown Trout	Yearling	407,300	461,150	425,000
	Fingerling	38,000	0	0
	Total	445,300	461,150	425,000
Coho Salmon	Yearling	197,100	110,000	90,000
	Fingerling	213,400	331,620	155,000
	Total	410,500	441,620	245,000
Lake Trout	Yearling	778,300	795,600	1,020,000
	Fingerling	232,000	310,000	180,000
	Total	1,010,300	1,105,600	1,200,000
Chinook Salmon	Fingerling	2,752,200	2,720,000	2,700,000
Rainbow Trout				
Washington Steelhead	Yearling	384,400	412,200	375,000
	Fingerling	75,000	180,000	0
	Total	459,400	592,200	375,000
Domestic	Yearling	93,800	94,110	100,000
	Fingerling	25,000	33,600	0
	Total	118,800	127,710	100,000
Skamania	Yearling	0	0	82,000
Atlantic Salmon	Yearling	49,500	33,320	200,000
	Fingerling	14,700	0	0
	Total	64,200	33,320	200,000
	TOTAL	5,260,700	5,481,600	5,327,000

[a]Stocking in both years includes surplus fingerlings.

TABLE 3. Number of salmon and trout (x 1000) planted in Province of Ontario waters of Lake Ontario from 1968 through 1990.

Species	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Coho Y	0	138	148	160	122	272	438	226	166	313	201	156	77	169	112	142	106	191	183	188	207	204	169
Coho F	0	0	0	0	0	0	0	0	0	0	0	130	172	165	0	76	0	0	90	129	104	87	66
Coho f	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	84	76	0	0
Chin f	0	0	0	89	190	0	225	0	0	0	393	147	18	12	270	125	662	703	598	514	516	541	497
Lake Y	0	0	0	0	0	0	0	0	194	288	200	201	383	387	391	372	493	729	852	1066	1024	1124	949
Lake F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	0	0	0
Brwn II+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0[b]	0[b]	0
Brwn Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	123	122	136	283	256	387	360	387
Brwn F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	0	0	27	14	62	0	0	0
Brwn f	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
Rbow Y	12	10	10	18	107	28	30	7	108	110	114	201	149	81	68	105	110	106	200	306	264	118	0
Rbow F	0	0	0	0	0	30	94	0	0	0	10	0	0	0	0	0	0	0	0	0	111	0	105
Rbow f	0	0	0	0	0	0	0	22	0	0	0	0	180	0	0	0	0	0	0	0	0	0	0
Atla Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	61	27
Atla F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	22	15	34
Spik Y	24	25	0	0	48	39	26	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Koka f	0	20	45	50	61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Koka fry	228	334	1982	678	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	264	527	2185	995	528	369	813	255[a]	474[a]	711[a]	918	835	979	821	889	943	1494	1893	2221	2662	2738	2511	2234

Legend: II+: Two year old fish
Y: Yearlings, stocked between January and June usually 5" to 9"
F: Fall fingerlings, stocked between September and December usually 3-1/2" to 6"
f: Spring fingerlings, stocked May and June usually 2-1/2" to 3"

[a] Does not include planting of 15,000 rainbow trout eggs in 1975 or lake trout eggs planted in 1976 (90,000) and 1977 (200,000)
[b] There were 346 and 275 adult brown trout stocked (spent brood stock) in 1988 and 1989, respectively.

TABLE 4. Number of salmon, trout and walleye (x 1000) planted in New York waters of Lake Ontario from 1968 through 1990.

Species	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Coho Y	25	119	294	122	230	215	147	452	178	39	40	175	0	0	307	396	289	351	194	80	300	197	110
Coho F	15	0	0	0	0	25	69	361	0	0	40	169	299	0	60	51	454	25	268	0	176	213	187
Coho af	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	144
Coho f	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85	0	80	0	0
Chin f	0	70	140	100	426	691	963	920	593	0	0	222	788	1468	1808	2759	3878	3022	2849	3111	2848	2752	2720
Chin F	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Y	0	0	0	0	0	66	128	0	63	0	505	492	1012	1031	1054	1086	1045	984	1012	818	768	778	796
Lake F	0	0	0	0	0	0	517	513	274	298	538	193	182	112	205	11	0	202	370	367	247	232	310
Lake II+	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Brwn Y	0	0	0	0	0	60	81	108	157	163	94	219	257	365	503	479	408	440	442	418	404	407	461
Brwn F	0	0	0	0	0	0	42	113	154	195	0		272	89	153	100	0	0	0	0	46	38	0
Brwn f	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	132	0	0	0	0	0	0	0
Rbow Y	0	0	0	0	0	0	19	0	54	50	41	41	85	76	38	108	93	84	80	91	77	94	94
Rbow F	0	0	0	0	0	0	10	99	104	67	125	167	411	147	96	105	105	105	23	40	150	25	34
Rbow f	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	140	0	549	0	0	0	0	0
Sthd Y	0	0	0	0	0	0	50	0	29	27	147	117	263	260	114	112	293	334	407	443	407	384	412
Sthd F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	10	55	129	308	75	180
Brok F	0	0	0	0	0	0	0	0	0	8	0	0	326	106	0	0	0	0	0	0	0	0	0
Atla Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49	25	55	55	58	32	50	33
Atla F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	7	6	15	0
Wall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	3	63	72	125
SALM	40	189	434	222	656	1066	2026	2566	1606	847	1530	1795	3895	3657	4441	5528	6590	6174	5840	5562	5849	5260	5482
WALL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	3	63	72	125
TOTALS	40	189	434	222	656	1066	2026	2566	1606	847	1530	1795	3895	3657	4441	5528	6590	6174	5860	5565	5912	5332	5607

Legend: II+: Two year old fish
Y: Yearlings, stocked between January and June usually 5" to 9"
F: Fall fingerlings, stocked between September and December usually 3-1/2" to 6"
af: Advanced spring fingerlings, usually stocked after June but prior to September
f: Spring fingerlings, stocked May and June usually 2-1/2" to 3"

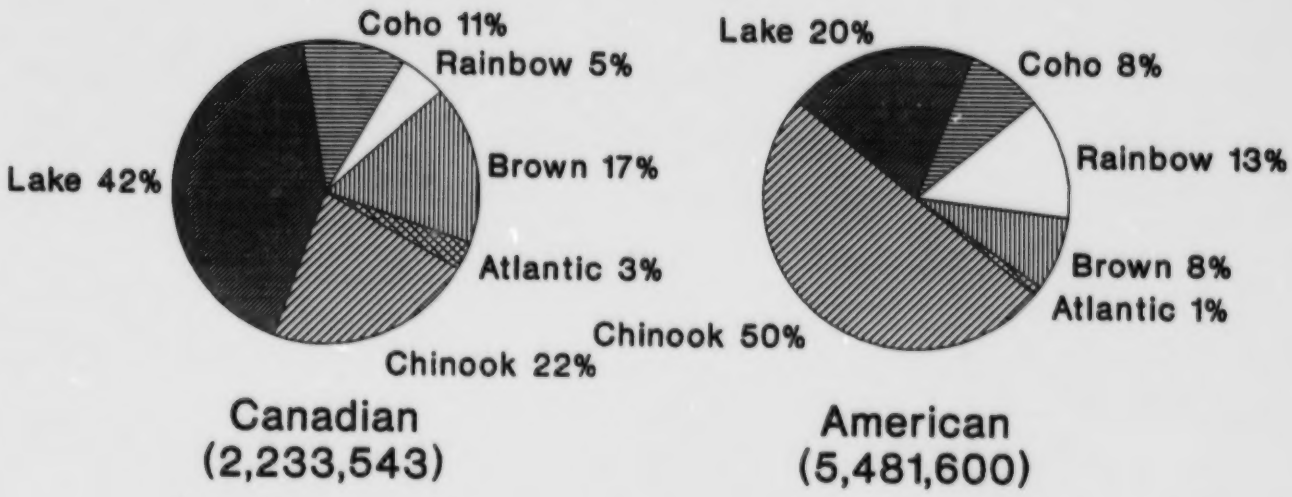
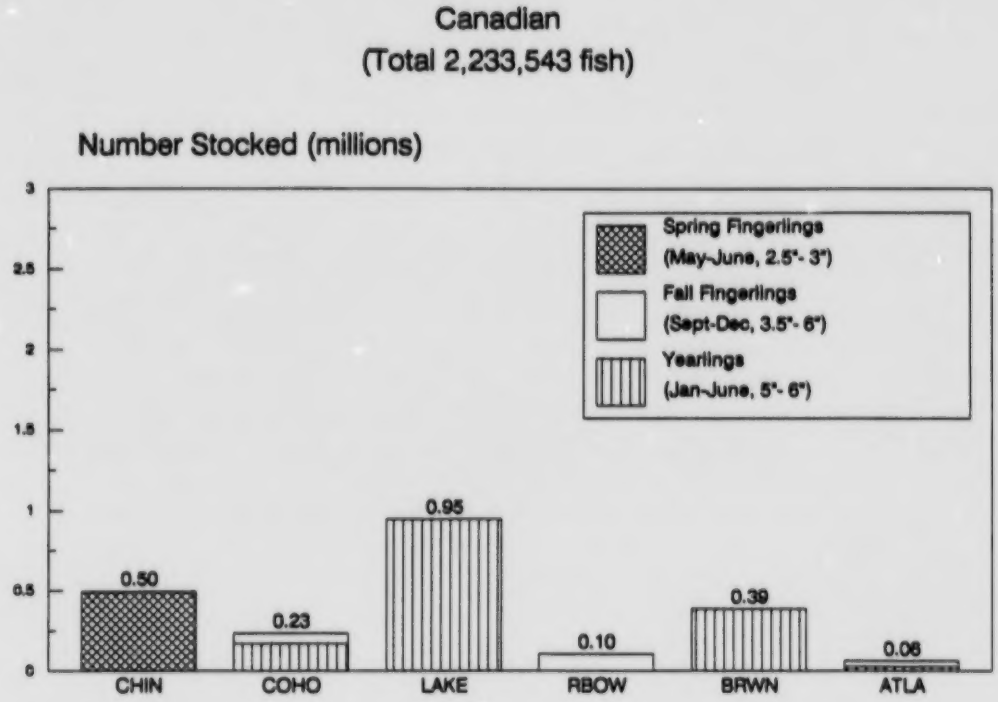


FIG. 1. Lake Ontario salmonid species mix stocked by OMNR and NYDEC in 1990.



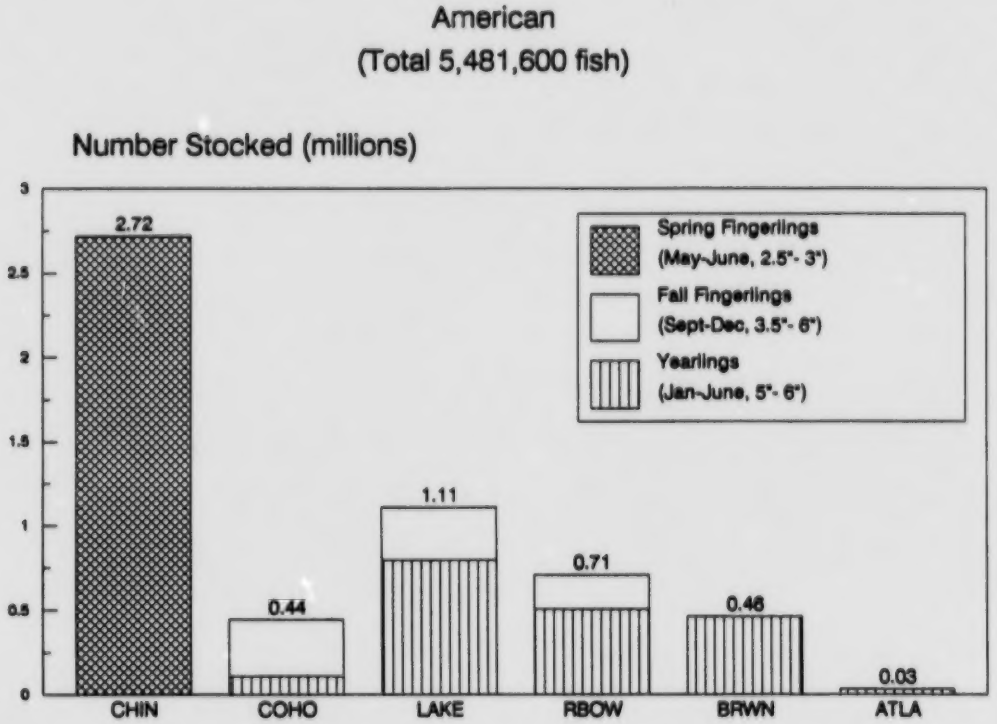


FIG. 2. Lake Ontario salmonid species mix stocked by OMNR and NYDEC in 1990 presented by age group.

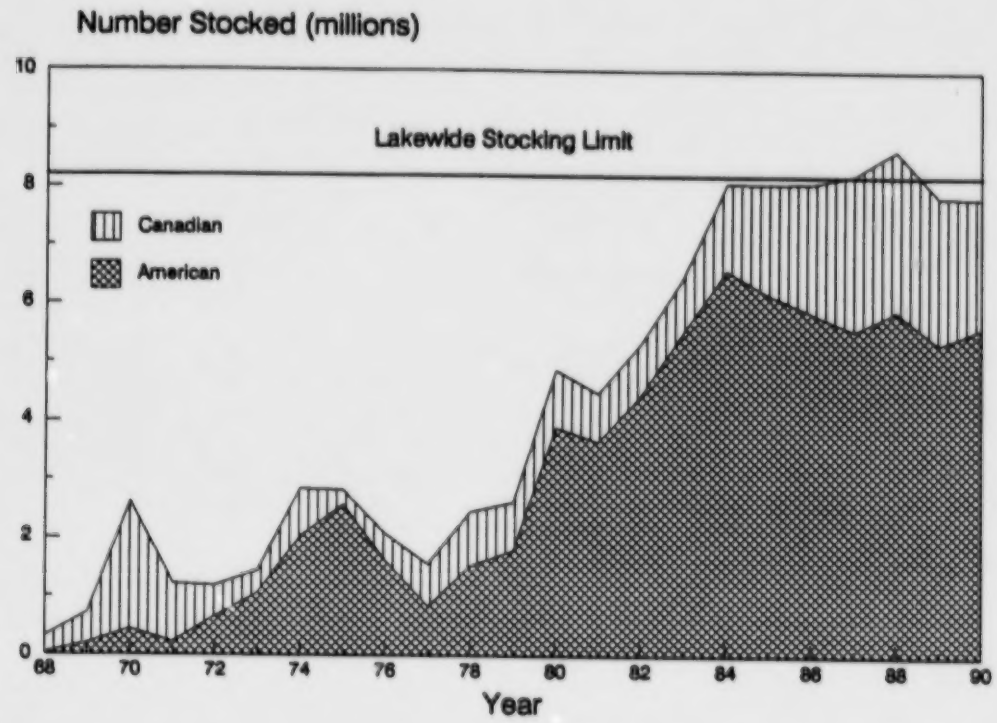


FIG. 3. Lake Ontario stocking trends (all species combined) from Canadian and American sources. Includes yearlings, all fingerlings, some fry and II+ fish. Also includes American stocked walleye beginning in 1986.

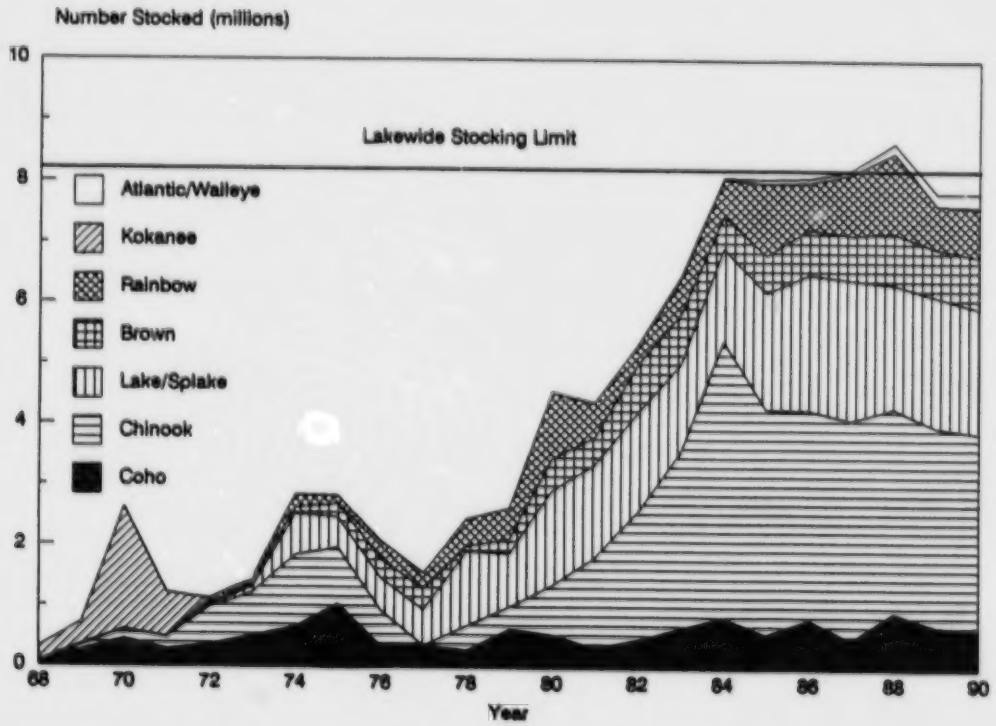


FIG. 4. Lake Ontario stocking trends, by species, for combined Canadian and American plantings. Includes all yearlings, all fingerlings, some fry and II+ fish. Canadian splake (1968-1976) are included with lake trout. Americans also stocked 326,000 and 106,000 brook trout in 1980 and 1981.

TABLE 5. Salmon and trout stocked in Province of Ontario waters of Lake Ontario in 1990.

Location	Month Stocked	Hatchery Reared	Strain or Egg Source	Age Months	# Fish/ Pound	Mark	Number Stocked
COHO SALMON							
Bronte Creek	09	Ringwood	Lake Ontario	08	32	AdRV	7,811
	03	Ringwood	Lake Ontario	14	22	RV	15,778
	03	Ringwood	Lake Ontario	14	22	Ad	15,781
BRONTE CREEK TOTAL							39,370
Credit River	09	Ringwood	Lake Ontario	08	33	AdRP	42,318
	03	Ringwood	Lake Ontario	14	21	Ad	106,173
CREDIT RIVER TOTAL							148,491
Port Dalhousie	10	Ringwood	Lake Ontario	09	26	AdRV	15,446
	03	Ringwood	Lake Ontario	14	23	RV	31,557
PORT DALHOUSIE TOTAL							47,003
TOTAL FALL FINGERLING COHO							65,575
TOTAL YEARLING COHO							169,289
TOTAL COHO SALMON							234,864
CHINOOK SALMON							
Bowmanville Creek	05	Ringwood	Lake Ontario	06	109	none	22,060
Bronte Creek	05	Ringwood	Lake Ontario	06	111	none	57,500
Cobourg Creek	05	Ringwood	Lake Ontario	06	111	none	25,000
Credit River	05	Ringwood	Lake Ontario	06	105	none	150,246
Hamilton Harbour	05	Ringwood	Lake Ontario	06	119	none	57,571
Oshawa Creek	05	Ringwood	Lake Ontario	06	109	none	30,000
Port Dalhousie	05	Ringwood	Lake Ontario	06	114	none	115,453
Wellington Harbour	05	Ringwood	Lake Ontario	06	123	none	39,517
TOTAL FINGERLING CHINOOK							497,347
RAINBOW TROUT							
Bronte Creek	04	Deer Lake	Ganaraska/ Normandale	11	42	RV	47,502
Credit River	04	Deer Lake	Ganaraska/ Normandale	11	42	RV	24,128
Duffins Creek	04	Deer Lake	Ganaraska/ Normandale	11	42	RV	24,128
Rouge River	04	Deer Lake	Ganaraska/ Normandale	11	42	RV	9,236
TOTAL YEARLING RAINBOW TROUT							104,994

TABLE 5. (Continued)

Location	Month Stocked	Hatchery Reared	Strain or Egg Source	Age Months	# Fish/ Pound	Mark	Number Stocked
ATLANTIC SALMON							
Credit River	11	Normandale	Landlocked Grand Lake Str. Maine, U.S.A.	10	12	LV	6,265
	03	Normandale	Landlocked Grand Lake Str. Maine, U.S.A.	11	10	AdRV	22,185
	04	Normandale	Anadromous LeHave, N.S.	15	11	AdLV	21,760
CREDIT RIVER TOTAL							50,210
Wilmot Creek	03	Normandale	Landlocked Grand Lake Str. Maine, U.S.A.	11	9	AdRV	1,550
	07	Normandale	Anadromous LeHave, N.S.	6	94	None	1,600
	11	Normandale	Anadromous LeHave, N.S.	10	12	LV	2,000
	03	Normandale	Anadromous LeHave, N.S.	14	12	AdLV	5,686
WILMOT CREEK TOTAL							8,836
TOTAL SPRING FINGERLING ATLANTIC							1,600
TOTAL FALL FINGERLING ATLANTIC							32,000
TOTAL FINGERLING ATLANTIC							33,600
TOTAL YEARLING ATLANTIC							27,446
TOTAL ATLANTIC SALMON							61,046
BROWN TROUT							
Ashbridges Bay	03	Harwood	Ganaraska/ Codrington	15	9	RV	7,453
	05	Harwood	Ganaraska/ Codrington	17	9	RV	13,089
ASHBRIDGES BAY TOTAL							20,542
Bluffer's Park	03	Harwood	Ganaraska/ Codrington	15	11	RV	23,763
Bronte Creek	04	Harwood	Ganaraska/ Codrington	16	7	RV	9,904
	05	Harwood	Ganaraska/ Codrington	17	6	RV	18,247
BRONTE CREEK TOTAL							28,151

TABLE 5. (Continued)

Location	Month Stocked	Hatchery Reared	Strain or Egg Source	Age Months	# Fish/ Pound	Mark[a]	Number Stocked
BROWN TROUT Continued							
Duffins Creek	03	Harwood	Ganaraska/ Codrington	15	10	RV	23,730
Fifty Point	05	Harwood	Ganaraska/ Codrington	17	7	RV	30,243
Ganaraska River	05	Codrington	Ganaraska/ Codrington	15	14	RV	23,000
Humber River	05	Codrington	Ganaraska/ Codrington	15	13	RV	4,600
	05	Harwood	Ganaraska/ Cordington	17	8	RV	17,363
HUMBER RIVER TOTAL							21,963
Millhaven	04	Codrington	Ganaraska/ Codrington	14	13	Ad	83,830
	05	Codrington	Ganaraska Codrington	15	12	Ad	24,482
MILLHAVEN TOTAL							108,312
Etobicoke Creek	05	Harwood	Ganaraska/ Codrington	17	10	RV	7,113
Oshawa Creek	05	Codrington	Ganaraska/ Codrington	15	12	RV	4,600
	05	Harwood	Ganaraska/ Codrington	17	8	RV	18,837
OSHAWA CREEK TOTAL							23,437
Port Dalhousie	05	Chatsworth	Ganaraska/ Codrington	14	9	RV	48,739
Rouge River	03	Harwood	Ganaraska/ Codrington	15	10	RV	27,725
TOTAL YEARLING BROWN TROUT							386,718

TABLE 5. (Continued)

Location	Month Stocked	Hatchery Reared	Strain or Egg Source	Age Months	# Fish/ Pound	Mark[a]	Number Stocked
LAKE TROUT							
Fifty Point	04	Deer Lake	Killala Lake/ Hills Lake	16	39	63-38-38 to 43	67,584
	05	Deer Lake	Killala Lake/ Hills Lake	16	39	63-38-38 to 43	50,257
FIFTY POINT TOTAL							117,841
Cobourg Harbour		Harwood	Lake Manitou	15	13	63-39-05 to-14	185,767
		Deer Lake	Killala Lake/ Hills Lake	16	46	63-39-01 to-04	130,514
COBOURG HARBOUR TOTAL							316,281
Main Duck Island		White Lake	Killala Lake/ Hills Lake	15	26	63-38-44 to-53	200,790
		Deer Lake	Killala Lake/ Hills Lake	16	45	63-38-54 to-60	134,600
		Harwood	Lake Manitou	16	9	63-39-15 to-24	179,062
MAIN DUCK ISLAND TOTAL							514,452
TOTAL YEARLING LAKE TROUT							948,574

[a]Coded wire tagged fish also have an adipose clip.

TABLE 6. Salmon, trout and walleye stocked in New York waters of Lake Ontario in 1990.

Area Stocked	Location	Grid/ Key	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age in Months	# Fish/ Pound	Marks Applied	Number Stocked
COHO SALMON YEARLINGS										
Beaverdam Brook	Smolt Release Pond	0.53-8	3/20-5/15 [a]	1989	Salmon R.	Salmon R.	15	21.0	None	90,000
Sodus Bay	West Pier	0.84	4/5	1989	Salmon R.	Salmon R.	14.5	20.0	None	10,000
Genesee River	Naval Militia Boat Ramp	0.117	4/5	1989	Salmon R.	Salmon R.	14.5	20.0	None	10,000
TOTAL YEARLINGS COHO SALMON										110,000
COHO SALMON FINGERLINGS										
North Sandy Creek	Rt. 3 Bridge	0.44	9/19	1990	Salmon R.	Salmon R.	9.5	32.0	None	12,210
South Sandy Creek	Rt. 3 Bridge	0.45	9/19	1990	Salmon R.	Salmon R.	9.5	32.0	None	12,210
Oswego River	Rt. 104 Bridge	0.66	9/19	1990	Salmon R.	Salmon R.	9.5	32.0	None	24,420
Sodus Bay	West Pier	0.84	9/21	1990	Salmon R.	Salmon R.	9.5	32.0	None	24,420
Genesee River	Naval Militia Boat Ramp	0.117	9/27	1990	Salmon R.	Salmon R.	10	29.9	None	20,350
Sandy Creek	Parkway Bridge	0.130	9/21	1990	Salmon R.	Salmon R.	9.5	30.0	None	24,420
Oak Orchard Ck.	Twin Bridges	0.138	9/28	1990	Salmon R.	Salmon R.	10	30.0	None	24,420
Eighteen Mile Creek	Olcott Harbour	0.148	9/24	1990	Salmon R.	Salmon R.	10	30.2	None	24,420
Niagara River	Lewiston Sand Docks	0.158	9/25	1990	Salmon R.	Salmon R.	10	30.2	None	20,350
TOTAL FALL FINGERLINGS COHO SALMON										187,220

[a]Coho salmon were stocked in the hatchery smolt release pond on March 20 and allowed to voluntarily migrate until May 15 when the pond was drained. Hatchery personnel estimated that approximately 60 percent had voluntarily migrated by May 15.

TABLE 6 (Continued)

Area Stocked	Location	Grid/ Key	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age in Months	# Fish/ Pound	Marks Applied	Number Stocked
COHO SALMON FINGERLINGS										
Lake Ont.	Hamlin	713	7/23	1990	Salmon R.	Salmon R.	7.5	58.0	None	71,400[b]
Lake Ont.	Olcott	708	7/19	1990	Salmon R.	Salmon R.	7.5	53.0	None	73,000[b]
TOTAL SURPLUS FINGERLING COHO SALMON										144,400
TOTAL FALL FINGERLING COHO SALMON										187,220
TOTAL YEARLING COHO SALMON										110,000
TOTAL COHO SALMON										441,620
CHINOOK SALMON FINGERLINGS										
Henderson Bay	Association Island Cut	423	5/25	1990	Salmon R.	Salmon R.	4	110	Ad-CWT 23-16-9	42,000
Henderson Bay	Association Island Cut	423	5/25	1990	Salmon R.	Salmon R.	4	110	None	18,000
HENDERSON BAY TOTAL										60,000
Lake Ont.	Southwick Beach St. Pk.	523	5/25	1990	Salmon R.	Salmon R.	4	95	Ad-CWT 23-16-8	40,500
Lake Ont.	Southwick Beach St. Pk.	523	5/25	1990	Salmon R.	Salmon R.	4	95	None	9,500
SOUTHWICK BEACH STATE PARK TOTAL										50,000
Lake Ont.	Stony Creek Boat Launch	0.40	6/5	1990	Salmon R.	Salmon R.	4	88	None	35,000
N. Sandy Creek	NY Rt. 3	0.44	5/29	1990	Salmon R.	Salmon R.	4	105	None	100,000
S. Sandy Creek	NY Rt. 3	0.45	5/29	1990	Salmon R.	Salmon R.	4	105	None	100,000
Beaverdam Brook	Salmon River Hatchery	0.53-8	5/24	1990	Salmon R.	Salmon R.	4	85	Ad-CWT 23-16-7	40,300
Beaverdam Brook	Salmon River Hatchery	0.53-8	6/18	1990	Salmon R.	Salmon R.	5	50	None	109,700
Beaverdam Brook	Salmon River Hatchery	0.53-8	6/18	1990	Salmon R.	Salmon R.	5	50	LP	300,000
BEAVERDAM BROOK TOTAL										450,000

[b] Surplus Stocking

TABLE 6. (Continued)

Area Stocked	Location	Grid/ Key	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age in Months	# Fish/ Pound	Marks Applied	Number Stocked
CHINOOK SALMON FINGERLINGS Continued										
Salmon R.	NY Rt. 3	0.53	5/31	1990	Salmon R.	Salmon R.	4	100	None	120,000
Oswego R.	Oswego Harbour	0.66	5/29	1990	Salmon R.	Salmon R.	4	90	None	225,000
Sterling Creek	Old State Road	0.73	5/31	1990	Salmon R.	Salmon R.	4	105	None	180,000
Sodus Bay	Outlet Channel	0.84	6/8	1990	Salmon R.	Salmon R.	4	111	None	180,000
Genesee R.	Naval Militia Boat Ramp	0.117	5/17	1990	Caledonia	Salmon R.	4	96	None	270,000
Sandy Ck.	NYDEC Boat Ramp	0.130	6/1	1990	Salmon R.	Salmon R.	4	95	None	180,000
Oak Orchard Creek	Twin Bridges	0.138	5/18 & 5/22	1990	Caledonia	Salmon R.	4	105	None	270,000
Eighteen Mile Creek	Olcott Harbour	0.148	6/11	1990	Salmon R.	Salmon R.	4	118	None	180,000
Twelve Mile Creek	Wilson Harbour	0.152	6/11	1990	Salmon R.	Salmon R.	4	118	None	60,000
Niagara R.	Lewiston Sand Docks	0.158	6/12	1990	Salmon R.	Salmon R.	4	114	None	260,000
TOTAL CHINOOK SALMON										2,720,000

TABLE 6. (Continued)

Area Stocked	Location	Grid/ Key	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age in Months	# Fish/ Pound	Marks Applied	Number Stocked
RAINBOW TROUT YEARLINGS										
Lake Ont.	Henderson Harbour	423	4/19 & 4/20	1989	Caledonia	Nashua	12	3.9	None	18,300
Lake Ont.	Selkirk Shores State Park	623	4/30	1989	Caledonia	Nashua	12	3.8	None	18,750
Lake Ont.	Sodus Point	819	4/26	1989	Caledonia	Nashua	12	3.0	None	15,000
Lake Ont.	Webster	816	4/9	1989	Caledonia	Nashua	11	4.5	None	7,500
Lake Ont.	Hamlin Beach State Park	713	4/3 & 4/9	1989	Caledonia	Nashua	11	4.8	None	15,000
Lake Ont.	Olcott Harbour	708	4/19	1989	Caledonia	Nashua	12	3.9	None	9,780
Lake Ont.	Wilson Harbour	707	4/10	1989	Caledonia	Nashua	11	4.5	None	9,780
TOTAL YEARLING RAINBOW TROUT										94,110
RAINBOW TROUT FINGERLINGS										
Lake Ont.	Sodus Point	819	12/4	1990	Caledonia	Randolph	12	7.5	None	24,600[b]
Lake Ont.	Fair Haven Beach St. Park	720	11/30	1990	Caledonia	Randolph	12	3.7	None	9,000[b]
TOTAL FINGERLING RAINBOW TROUT										33,600
RAINBOW TROUT FRY										
Genesee R.	Naval Militia Boat Ramp	0.117	12/18	1990	Caledonia	Randolph	0	1740	None	98,000[c]
TOTAL RAINBOW TROUT FRY										98,000[c]
TOTAL FINGERLING RAINBOW TROUT										33,600
TOTAL YEARLING RAINBOW TROUT										94,110
TOTAL RAINBOW TROUT (excluding fry)										127,710

[b] Surplus Stocking
[c] Surplus - not added to species totals

TABLE 6 (Continued)

Area Stocked	Location	Grid/ Key	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age in Months	# Fish/ Pound	Marks Applied	Number Stocked
STEELHEAD TROUT YEARLINGS										
Black River	Dexter	0.19	4/16	1989	Salmon R.	Washington-Salmon River	13	15.0	None	20,000
Stony Ck.	Stony Creek Road Bridge	0.40	4/11	1989	Caledonia	Washington-Salmon River	10	9.0	None	18,000
South Sandy Ck.	Below NY Rt. 3	0.44	4/10	1989	Caledonia	Washington-Salmon River	10	9.5	None	25,000
Beaverdam Brook	Salmon R. Hatchery	0.53-8	5/15	1989	Caledonia	Washington-Salmon River	10	9.5	LV	45,000
Beaverdam Brook	Salmon R. Hatchery	0.53-8	5/15	1989	Salmon R.	Washington-Salmon River	14	15.0	LV	45,000
Orwell Brook	Lower 3 Bridges	0.53-6	4/9	1989	Salmon R.	Washington-Salmon River	13	15.0	LV	10,000
Spring Bk. Reservoir	Reservoir	0.53-2-P.6	4/10	1989	Salmon R.	Washington-Salmon River	13	15.0	LV	10,000
Salmon R.	Pineville	0.53	4/9	1989	Salmon R.	Washington-Salmon River	13	15.0	LV	5,000
Salmon R.	Pineville	0.53	5/1	1989	Caledonia	Washington-Salmon River	11	6.2	None	10,200[b]
Salmon R.	Co. Rt. 2A	0.53	4/10	1989	Caledonia	Washington-Salmon River	10	15.0	LV	5,000
SALMON RIVER SYSTEM TOTAL										130,200

[b] Surplus Stocking

TABLE 6. (Continued)

Area Stocked	Location	Grid/ Key	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age in Months	# Fish/ Pound	Marks Applied	Number Stocked
STEELHEAD TROUT YEARLINGS Continued										
Oswego R.	Port Authority	0.66	4/6	1989	Caledonia	Washington-Salmon River	10	12.0	None	18,000
Oswego R.	Port Authority	0.66	4/12	1989	Salmon R.	Washington-Salmon River	13	15.0	None	15,000
OSWEGO RIVER TOTAL										33,000
Maxwell Ck.	Mouth to Trib. 2	0.85	4/17	1989	Caledonia	Washington-Salmon River	10	7.9	None	18,000
Irondequoit Creek	Audubon Property	0.108	4/6 & 4/16	1989	Caledonia	Washington-Salmon River	10	8.6	None	24,000
Genesee R.	Naval Militia Boat Ramp	0.117	4/10	1989	Salmon R.	Washington-Salmon River	13	15.0	None	20,000
Salmon Ck.	Lower Portion	0.125	4/16	1989	Caledonia	Washington-Salmon River	10	8.5	None	10,000
Sandy Ck.	Rt. 18	0.130	4/10	1989	Caledonia	Washington-Salmon River	10	7.0	None	13,300
Oak Orchard Ck.	Twin Bridges	0.138	4/11	1989	Caledonia	Washington-Salmon River	10	9.0	None	20,000
Keg Ck.	Rt. 18	0.148	4/19	1989	Caledonia	Washington-Salmon River	10	7.0	None	11,100
E. Branch Twelve Mile Creek	Near Mouth	0.152	4/18	1989	Caledonia	Washington-Salmon River	10	7.0	None	13,300
Twelve Mile Creek	Rt. 18 Bridge	0.152A	4/18	1989	Caledonia	Washington-Salmon River	10	7.0	None	13,300
Niagara R.	Lewiston Sand Docks	0.158	4/6 & 4/13	1989	Caledonia	Washington-Salmon River	10	8.3	None	43,000
TOTAL YEARLING STEELHEAD										412,200

TABLE 6. (Continued)

Area Stocked	Location	Grid/ Key	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age in Months	# Fish/ Pound	Marks Applied	Number Stocked
STEELHEAD TROUT FINGERLINGS										
Black River	Dexter	0.19	9/19	1990	Salmon R.	Washington-Lake Ontario	3	120	None	45,000
Lake Ont.	Selkirk Shores St. Park Pier	623	9/18	1990	Salmon R.	Washington-Lake Ontario	3	120	None	45,000
Lake Ont.	Sodus Point Pier	819	9/18	1990	Salmon R.	Washington-Lake Ontario	3	120	None	45,000
Niagara R.	Lewiston	0.158	9/20	1990	Salmon R.	Washington-Lake Ontario	3	120	None	45,000
TOTAL SURPLUS FINGERLING STEELHEAD										180,000
TOTAL YEARLING STEELHEAD										412,200
TOTAL STEELHEAD										592,200
ATLANTIC SALMON YEARLINGS										
Lake Ont.	Irondequoit Bay Outlet	0.108	5/1	1989	Caledonia	Little Clear	16	13.2	None	8,944
Lake Ont.	Irondequoit Bay Outlet	0.108	6/8	1989	Caledonia	Little Clear	17	9.5	None	3,296
Oswego River	Oswego Harbor	0.66	5/17	1989	Catskill	Little Clear	16	8.8	None	13,600
Black River	Dexter	0.19	5/17	1989	Catskill	Little Clear	16	8.8	None	7,480
TOTAL YEARLING ATLANTIC SALMON										33,320

TABLE 6. (Continued)

Area Stocked	Location	Grid/ Key	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age in Months	# Fish/ Pound	Marks Applied	Number Stocked
BROWN TROUT YEARLINGS										
Lake Ont.	Henderson Bay	423	4/23	1989	Salmon R.	Rome Lab	16.5	6.0	None	19,230
Lake Ont.	Ray Bay	523	4/24	1989	Salmon R.	Rome Lab	16.5	6.0	None	20,100
Lake Ont.	Montario Pt.	523	4/25	1989	Salmon R.	Rome Lab	16.5	6.0	None	20,100
Lake Ont.	Selkirk	623	5/4	1989	Salmon R.	Rome Lab	16.5	8.0	LV-Ad	16,500
Lake Ont.	Selkirk	623	5/7	1989	Catskill	Seeforellen/ Catskill	14.5	9.5	LV	20,000
Lake Ont.	Selkirk	623	5/29	1989	Catskill	Seeforellen/ Catskill	15.5	6.9	Ad	8,450
Lake Ont.	Selkirk	623	6/18	1989	Salmon R.	Rome Lab	18	4.0	None	8,500
SELKIRK TOTAL										53,450
Lake Ont.	Oswego	721	5/3	1989	Salmon R.	Rome Lab	16.5	8.0	LV-Ad	16,500
Lake Ont.	Oswego	721	5/3	1989	Catskill	Seeforellen/ Catskill	14.5	6.4	LV	20,000
OSWEGO TOTAL										36,500
Lake Ont.	Fair Haven	720	4/30 & 5/2	1989	Salmon R.	Rome Lab	16.5	6.0	None	31,000
Lake Ont.	Sodus	819	5/2 & 5/4	1989	Salmon R.	Rome Lab	16.5	6.7	None	29,300
Lake Ont.	Pultneyville	817	5/1 & 5/4	1989	Salmon R.	Rome Lab	16.5	7.0	None	21,830
Lake Ont.	Webster	816	5/1	1989	Salmon R.	Rome Lab	16.5	6.0	None	21,240
Lake Ont.	Irondequoit	815	5/3	1989	Salmon R.	Rome Lab	16.5	8.0	None	22,130
Lake Ont.	Rochester	815	5/1	1989	Salmon R.	Rome Lab	16.5	8.0	None	27,280
Lake Ont.	Braddock's Point	815	5/21	1989	Salmon R.	Rome Lab	17	8.0	None	21,450
Lake Ont.	Hamlin	713	5/7	1989	Salmon R.	Rome Lab	16.5	8.0	None	33,540
Lake Ont.	Point Breeze	711	5/22	1989	Salmon R.	Rome Lab	17	6.0	None	34,000
Lake Ont.	Olcott	708	4/2 & 4/3	1989	Caledonia	Rome Lab	15	5.5	None	35,000
Lake Ont.	Wilson	707	4/4 & 4/12	1989	Caledonia	Rome Lab	15.5	5.0	None	35,000
TOTAL YEARLING BROWN TROUT										461,150

TABLE 6. (Continued)

Area Stocked	Location	Grid/ Key	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age in Months	# Fish/ Pound	Marks Applied	Number Stocked
LAKE TROUT YEARLINGS										
Lake Ont.	Olcott	708	4/24	1989	Allegheny	Seneca	17	10.4	60-45-59	24,600
Lake Ont.	Olcott	708	5/14	1989	Allegheny	Seneca	17	10.5	60-45-43	40,000
Lake Ont.	Olcott	708	5/14	1989	Allegheny	Ontario	17	11.8	60-46-02	41,000
OLCOTT TOTAL										105,600
Lake Ont.	Hamlin	713	4/23	1989	Allegheny	Seneca	17	12.5	60-45-60	50,000
Lake Ont.	Hamlin	713	5/16	1989	Allegheny	Seneca	17	12.3	60-45-62	35,000
Lake Ont.	Hamlin	713	5/16	1989	Allegheny	Ontario	17	8.1	60-45-50	41,000
Lake Ont.	Hamlin	713	5/16	1989	Allegheny	Superior	17	8.3	60-45-41	40,000
HAMLIN TOTAL										166,000
Lake Ont.	Sodus	818	4/23	1989	Allegheny	Seneca	17	13.3	60-45-58	51,000
Lake Ont.	Sodus	818	5/10	1989	Allegheny	Ontario	17	11.1	60-46-03	41,000
Lake Ont.	Sodus	818	5/10	1989	Allegheny	Seneca	17	9.4	60-45-55	35,000
Lake Ont.	Sodus	818	5/10	1989	Allegheny	Superior	17	8.4	60-45-40	40,000
SODUS TOTAL										167,000
Lake Ont.	Selkirk	623	5/11	1989	Allegheny	Ontario	17	7.8	60-45-51	41,000
Lake Ont.	Selkirk	623	5/11& 5/15	1989	Allegheny	Seneca	17	10.1	60-45-45	40,000
Lake Ont.	Selkirk	623	5/15	1989	Allegheny	Seneca	17	10.1	60-45-28	41,000
SELKIRK TOTAL										122,000
Lake Ont.	Stony	422	5/8	1989	Allegheny	Seneca	17	10.2	60-45-46	40,000
Lake Ont.	Stony	422	5/8	1989	Allegheny	Seneca	17	11.0	60-45-44	40,000
Lake Ont.	Stony	422	5/8	1989	Allegheny	Superior	17	8.3	60-45-42	40,000
Lake Ont.	Stony	422	5/8	1989	Allegheny	Ontario	17	12.4	60-46-04	40,000
STONY TOTAL										160,000
Lake Ont.	Charity	422	5/23	1989	Allegheny	Ontario	17	10.2	60-45-47	40,000
Lake Ont.	Charity	422	5/23	1989	Allegheny	Seneca	17	9.4	60-45-56	35,000
CHARITY TOTAL										75,000
TOTAL YEARLING LAKE TROUT										795,600

TABLE 6. (Continued)

Area Stocked	Location	Grid/ Key	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age in Months	# Fish/ Pound	Marks Applied	Number Stocked
LAKE TROUT FINGERLINGS										
Lake Ont.	Olcott	708	10/16	1990	Allegheny	Ontario	10	35	60-46-01	62,000
Lake Ont.	Hamlin	713	10/16	1990	Allegheny	Ontario	10	35	60-46-12	62,000
Lake Ont.	Sodus	818	10/17	1990	Allegheny	Ontario	10	33	60-46-13	62,000
Lake Ont.	Selkirk	623	10/17	1990	Allegheny	Ontario	10	35	60-46-14	62,000
Lake Ont.	Stony	422	10/18	1990	Allegheny	Ontario	10	42	60-46-15	62,000
TOTAL FINGERLING LAKE TROUT										310,000
TOTAL YEARLING LAKE TROUT										795,600
TOTAL LAKE TROUT										1,105,600
WALLEYE FINGERLINGS										
Niagara R.	Lewiston	0.158	late June - early July	1990	NRAA [d] Ponds	Constantia	4	3/4"- 3-1/2"	None	24,000
Lake Ont.	Fairhaven	720	late June - early July	1990	Sanford [e] Bait Farms	Constantia	4	2"	None	12,000
Lake Ont.	Blind Sodus	720	late June - early July	1990	Sanford Bait Farms	Constantia	4	2"	None	6,000
Lake Ont.	Port Bay	819	late June - early July	1990	Sanford Bait Farms	Constantia	4	1-1/2"- 4-1/2"	None	18,000
Lake Ont.	Sodus Bay	0.84	late June - early July	1990	Sanford Bait Farms	Constantia	4	1-1/2"- 3"	None	65,000
TOTAL WALLEYE										125,000

[d] Niagara River Anglers Association - 10 ponds, 1/2 acre each
[e] Sanford Bait Farms - 11 ponds, 1/4 acre to 1 acre, total of 9-1/2 acres

TABLE 7. Important deviations from the proposed stocking numbers by OMNR and NYDEC in 1990.

Species	Agency	Number (x 1000)	Reason
Lake Trout	NYDEC	- 225Y + 130F	Attempting to produce recently required strains is taking time.
	OMNR	- 201Y + 332af	Shortfall, in part, due to Hills Lake Hatchery renovation.
Coho	NYDEC	- 210Y + 332af	Policy change underway to stock yearlings at Salmon River, to maintain brood stock and to stock all others as summer fingerlings.
	OMNR	+ 9Y - 14F	Net shortfall due to premature hatch mortality.
Chinook	OMNR	- 153F	Hatchery (Ringwood) cannot meet 650,000 chinook fingerling target without expansion of early rearing facility. Chinook also experienced premature hatch mortality.
Rainbow Trout	NYDEC	- 21Y + 10F	Statewide shortage of yearlings. Extra fingerlings stocked to replace shortfall.
	OMNR	- 70Y	Hatchery production shortfall.
Steelhead	NYDEC	+ 82Y + 180F	Better than anticipated survival of all year classes.
Skamania	NYDEC	- 82F	No yearlings available due to disease.
Brown Trout	NYDEC	- 39Y	Statewide shortage of yearlings.
	OMNR	- 48Y	Hatchery production shortfall.
Atlantic Salmon	NYDEC	- 16Y	Hatchery renovation underway.
	OMNR	- 23Y + 34F	Changes due to fall fingerling stocking experiments.

Legend: Y: Yearlings, stocked between January and June, usually 5" to 9"
F: Fall fingerlings, stocked between September and December usually 3-1/2" to 6"
af: Advanced spring fingerlings, usually stocked after June but prior to September
f: Spring fingerlings, stocked May and June usually 2-1/2" to 3".

TABLE 8. Proposed 1991 stocking in Province of Ontario waters of Lake Ontario.

Species	Location	Quantity	Age
COHO SALMON	Credit River	100,000	Yearling
	Bronte Creek	30,000	Yearling
	Martindale Pond	30,000	Yearling
	Credit River	50,000	Fall Fingerling
	Bronte Creek	10,000	Fall Fingerling
	Martindale Pond	20,000	Fall Fingerling
		240,000	
CHINOOK SALMON	Credit River	200,000	Spring Fingerling
	Hamilton Harbour	75,000	Spring Fingerling
	Bronte Creek	75,000	Spring Fingerling
	Port Dalhousie	150,000	Spring Fingerling
	Cobourg Area	40,000	Spring Fingerling
	Oshawa Creek	30,000	Spring Fingerling
	Bowmanville Creek	30,000	Spring Fingerling
	Wellington Harbour	50,000	Spring Fingerling
		650,000	
BROWN TROUT	12 Mile Creek	35,000	Yearling
	Jordan Harbour	35,000	Yearling
	Collins Bay	55,000	Yearling
	Parrott's Bay	55,000	Yearling
	Bronte Creek	35,000	Yearling
	50 Mile Point	35,000	Yearling
	Ganaraska River	25,000	Yearling
	Oshawa Creek	25,000	Yearling
	Humber River	25,000	Yearling
	Rouge River	30,000	Yearling
	Duffins Creek	25,000	Yearling
	Toronto Island	30,000	Yearling
	Bluffer's Park	25,000	Yearling
		435,000	
LAKE TROUT	50 Mile Point	200,000	Yearling
	Port Hope	200,000	Yearling
	Scotch Bonnet Shoal	250,000	Yearling
	Charity-Main Duck Sh.	500,000	Yearling
		1,150,000	
RAINBOW TROUT	Credit River	100,000	Yearling
	Bronte Creek	75,000	Yearling
		175,000	
ATLANTIC SALMON	Credit River	40,000	Yearling
	Wilmot Creek	10,000	Yearling
		50,000	
CANADIAN PROPOSED TOTAL ALL SPECIES		2,700,000	

TABLE 9. Proposed 1991 stocking of New York waters in Lake Ontario.

Region	Location	Key	Number	Age
CHINOOK SALMON				
6	Southwicks Beach	523	50,000	4 months
6	Associated Island	423	60,000	4 months
6	Stony Creek	0.40	35,000	4 months
6	North Sandy Creek	0.45	90,000	4 months
6	South Sandy Creek	0.45	90,000	4 months
7	Salmon River	0.53	300,000	4 months
7	Lower Salmon River	0.53	270,000	4 months
7	Oswego River	0.66	225,000	4 months
7	Little Sodus Bay	0.73	180,000	4 months
8	Sodus Bay	0.84	180,000	4 months
8	Genesee River	0.117	270,000	4 months
8	Sandy Creek	0.130	180,000	4 months
8	Oak Orchard Creek	0.138	270,000	4 months
9	Eighteen Mile Creek	0.148	180,000	4 months
9	Twelve Mile Creek	0.152	60,000	4 months
9	Lower Niagara River	0.157	260,000	4 months
		TOTAL	2,700,000	
COHO SALMON				
7	Salmon River	0.53	90,000	Yearling
8	Sodus Point	0.84	26,000	Fingerling
8	Genesee River	0.117	22,000	Fingerling
8	Sandy Creek	0.130	26,000	Fingerling
8	Oak Orchard Creek	0.138	26,000	Fingerling
9	Eighteen Mile Creek	0.148	30,000	Fingerling
9	Niagara River	0.157	25,000	Fingerling
		TOTAL	245,000	
ATLANTIC SALMON				
	Black River	0.19	75,000	Yearling
7	Oswego River	0.66	35,000	Yearling
8	Hamlin Beach	713	20,000	Yearling
8	Irondequoit Bay	815	20,000	Yearling
8	Sodus Point	0.84	20,000	Yearling
9	Niagara River	0.157	30,000	Yearling
		TOTAL	200,000	

TABLE 9. (Continued)

Region	Location	Key	Number	Age
DOMESTIC BROWN TROUT				
6	Montario Point	523	19,000	Yearling
6	Ray Bay	523	19,000	Yearling
7	Fairhaven Beach St. Pk.	720	35,000	Yearling
7	Oswego Harbour	721	16,500	Yearling
7	Selkirk Shores St. Pk.	623	16,500	Yearling
8	Hamlin Beach St. Pk.	713	36,000	Yearling
8	Irondequoit	815	23,000	Yearling
8	Rochester at Kodak	815	30,000	Yearling
8	Braddocks	815	23,000	Yearling
8	Webster	816	23,000	Yearling
8	Point Breeze	711	38,000	Yearling
8	Sodus Point	819	32,000	Yearling
8	Pultneyville	817	24,000	Yearling
9	Wilson	707	25,000	Yearling
9	Olcott	708	25,000	Yearling
		TOTAL	385,000	
SEEFORELLEN BROWN TROUT				
7	Oswego Harbor	721	20,000	Yearling
7	Selkirk Shores St. Pk.	623	20,000	Yearling
		TOTAL	40,000	
LAKE TROUT				
6	Dablon Point	322-323	120,000	Yearling
6	Dablon Point	322-323	50,000	Yearling
6	Stony Point	422-423	120,000	Yearling
6	Stony Point	422-423	50,000	Yearling
6	Stony Point	422-423	60,000	Fingerling
7	Selkirk	623	120,000	Yearling
7	Selkirk	623	50,000	Yearling
7	Selkirk	623	30,000	Fingerling
8	Hamlin Beach	713	120,000	Yearling
8	Hamlin Beach	713	50,000	Yearling
8	Hamlin Beach	713	30,000	Fingerling
8	Sodus	819	120,000	Yearling
8	Sodus	819	50,000	Yearling
8	Sodus	819	30,000	Fingerling
9	Niagara	806	120,000	Yearling
9	Niagara	806	50,000	Yearling
9	Niagara	806	30,000	Fingerling
		TOTAL	1,020,000	Yearling
			180,000	Fingerling

TABLE 9. (Continued)

Region	Location	Key	Number	Age
WASHINGTON STEELHEAD				
6	Black River	0.19	47,000	Yearling
6	Stony Creek	0.40	18,000	Yearling
6	South Sandy Creek	0.45	25,000	Yearling
7	Salmon River	0.53	120,000	Yearling
7	Oswego River	0.66	15,000	Yearling
8	Genesee River	0.117	20,000	Yearling
8	Irondequoit Creek	0.108	24,000	Yearling
8	Salmon Creek	0.125	10,000	Yearling
8	Sandy Creek	0.130	13,300	Yearling
8	Oak Orchard Creek	0.138	20,000	Yearling
9	Keg Creek	0.146	11,100	Yearling
9	E. Br. Twelve Mile Creek	0.152	13,300	Yearling
9	Twelve Mile Creek	0.152A	13,300	Yearling
9	Lower Niagara River	0.157	25,000	Yearling
		TOTAL	375,000	
SKAMANIA STEELHEAD				
6	Black River	0.19	18,000	Yearling
7	Salmon River	0.53	28,000	Yearling
8	Maxwell Creek	0.85	18,000	Yearling
9	Niagara River	0.157	18,000	Yearling
		TOTAL	82,000	
DOMESTIC RAINBOW TROUT				
7	Selkirk Shores St. Pk.	623	25,000	Yearling
8	Hamlin Beach St. Pk.	713	20,000	Yearling
8	Webster	816	10,000	Yearling
8	Sodus	819	20,000	Yearling
9	Wilson	707	12,500	Yearling
9	Olcott	708	12,500	Yearling
		TOTAL	100,000	
AMERICAN PROPOSED TOTAL ALL SPECIES			5,327,000	

Status of Selected Fish Populations In Eastern Lake Ontario

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Lake Ontario Fisheries Unit 1990 Annual Report, LOA 91.1 (Chapter 18).

Analysis of the eastern Lake Ontario assessment index gillnetting series over the period 1986-1990, supplemented by selected longer-term research gillnetting series in the Bay of Quinte, are used to update the status of of yellow perch, lake herring, brown bullhead, white perch, smallmouth bass and walleye. Catches of lake herring and walleye have increased in the eastern outlet basin. Catches of other species show little change. Marketable size yellow perch abundance has remained low since 1981.

Recommendations

1. Maintain the eastern Lake Ontario assessment gillnetting program.
2. Process available yellow perch calcified tissue samples to determine historical changes in age structure and growth.

Introduction

The assessment component of the Lake Ontario Fisheries Unit (LOFU) has maintained an index gillnetting program at three sites in the eastern outlet basin of Lake Ontario since 1986, and the program was extended in 1988 to three additional sites; two in central Lake Ontario, and one site at Brighton. The program complements other historical gillnet series initiated by the research component of LOFU and provides indices of abundance for several fish species of direct management interest. Moreover, the program was intended to provide long-term indices of fish population abundance in eastern Lake Ontario to detect long-term fish community changes.

This report updates the status of yellow perch, lake herring, brown bullhead, white perch, smallmouth bass, and walleye in eastern Lake Ontario. The status of lake whitefish and lake trout are updated in Stewart (1991) and Schneider et al. (1991), respectively. A more detailed account of the status of walleye is provided in Mathers (1991).

Methods

Data were collected at 6 depth stratified transects (2.5-27.5 m) in eastern Lake Ontario and one single depth site (Middle Ground) near Brighton (Fig.1). The 2.5 m depth strata was dropped from the design in 1990. This depth was fished inconsistently in previous years due to excessive mosa build up in the nets, and thus was not considered in this report. At each depth, a gang of multifilament gillnet consisting of panels of differing mesh size (38, 51, 64, 76, 89, 102, 114, and 127 mm) was fished overnight. The sampling was repeated three times at each transect on a rotational basis during July and August. The survey design and sampling protocols have, for the most part, remained the same as reported in previous years (Mathers 1989; Bowlby and Mathers 1989).

Catches from each gillnet panel (mesh size) were extrapolated to 100 m of net and then added by species to produce a standardized catch for each gillnet lift. Based on the relationship between the mean and variance of the catches (Taylor's Power Law, Elliot 1979) all data were transformed ($X^{0.25}$) prior to statistical analysis. The sum of catches across all depths was considered as one sample. Data were analyzed in two site groups (Fig. 1); eastern outlet basin (Flatt Point, Grape Island, and Melville Shoal, 1986-1990); and central/west Lake Ontario (Wellington, Rocky Point, and Brighton 1988-1990). Total catches were subject to a two factor ANOVA including only year and area as factors (i.e. ignoring depth and temperature). Differences among years were tested using a Student-Newman-Keuls multiple range test ($p = 0.05$). Graphical trends in the research Bay of Quinte gillnetting (Hurley 1991), and long-term sampling at a single depth site at the Middle Ground site were examined to complement these analyses.

FIG. 1. Location of index gillnet transects.

TABLE 1. Results of two factors ANOVA's and test of hypotheses of differences in mean catch among years. All hypotheses were tested using Student-Newman-Keuls multiple range test (p = 0.05). Years with the same letter are not significantly different. The value of the letters indicate the rank of the group means (A = highest, C = lowest). Analysis of both site groups are included in this table. Comparison of ranks across site groups is inappropriate.

Species	Site Group	Significant model terms	Tests of year differences				
			86	87	88	89	90
Lake herring	Outlet basin	year, area			A	A	A
			B	B	B	B	
	Central/west	year, area			A	A	A
Walleye	Outlet basin	year, area			A	A	A
			B	B	B		
	Central/west	year, area				A	
					B		B
Yellow perch	Outlet basin	year, area	A		A	A	A
			B		B	B	
			C	C	C		
	Central/west	area			A	A	A
Brown bullhead	Outlet basin	none	A	A	A	A	A
	Central/west	year, area			A	A	A
White perch	Outlet basin	area	A	A	A	A	A
Smallmouth bass	Outlet basin	year, area		A	A	A	A
			B	B	B	B	

Results

Eastern Outlet Basin

Catches of lake herring and walleye have increased in the eastern outlet basin in recent years (Fig. 2 and 3, Table 1). Although some differences among years were observed for yellow perch catches, these differences cannot be interpreted as increasing or decreasing trends (Fig. 4, and Table 1). No detectable differences in catches were observed for brown bullhead and white perch in the eastern outlet basin (Fig. 5 and 6, Table 1). Catches of smallmouth bass show some tendency towards increase, with mean catches in later years being higher than those of early years (Fig. 7, Table 1).

Central/west Lake Ontario

With the exception of a higher catch of walleye in 1989, there were no significant differences observed in the central/west Lake Ontario sites for any species during the years 1988-1990 (Table 1). Smallmouth bass and white perch catches in central/west Lake Ontario were too low for meaningful comparisons, and were not tested.

Long-term trends in yellow perch catches at the Middle Ground site illustrate the lower overall catch rates in recent years (Fig. 8) and continued poor catches of marketable fish (≥7.5 inches total length) (Fig. 9). Low catches of larger perch are also evident at other sites (Fig. 10 and 11).

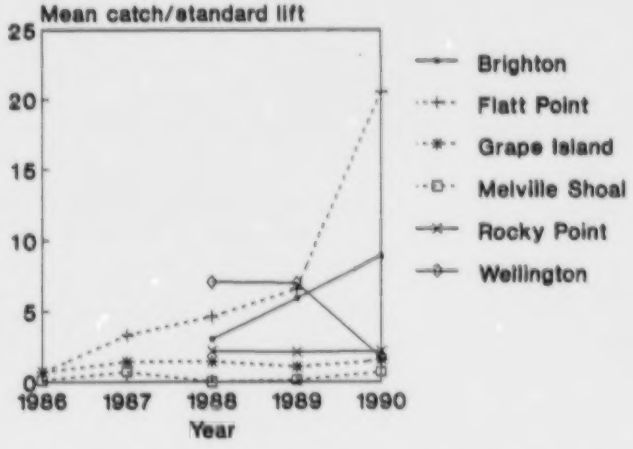

FIG. 2. Mean catches of lake herring at transects in eastern Lake Ontario during July and August.

Bay of Quinte

In the Bay of Quinte, research gillnet catches of yellow perch were down from 1989 (Fig 12). White perch catches increased in 1989, but remain low since their decline in 1978 (Fig. 13).

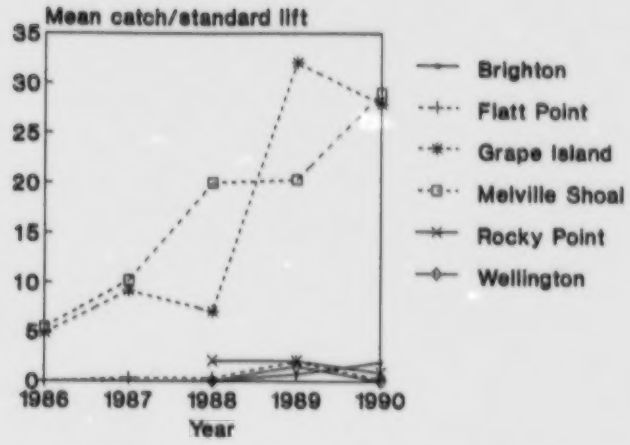

FIG. 3. Mean catches of walleye at transects in eastern Lake Ontario during July and August.

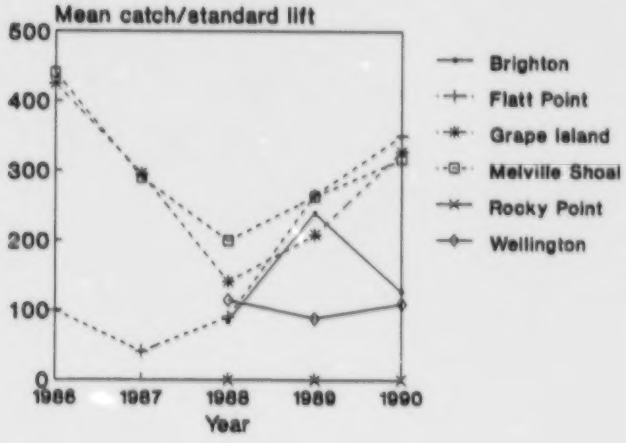

FIG. 4. Mean catches of yellow perch at transects in eastern Lake Ontario during July and August.

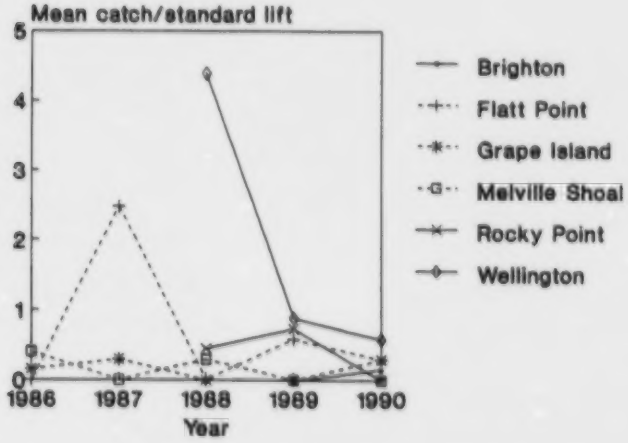

FIG. 5. Mean catches of brown bullhead at transects in eastern Lake Ontario during July and August.

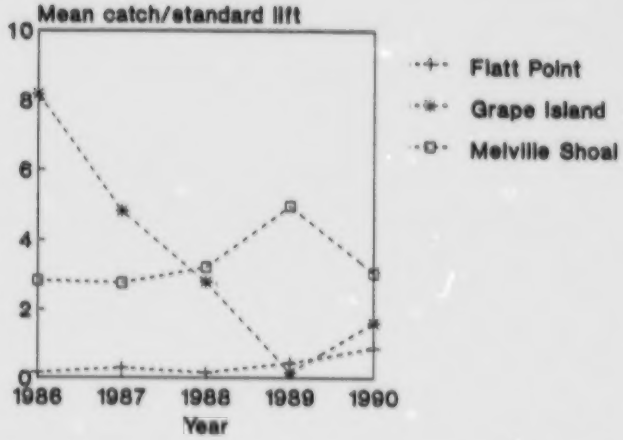

FIG. 6. Mean catches of white perch at transects in eastern Lake Ontario during July and August.

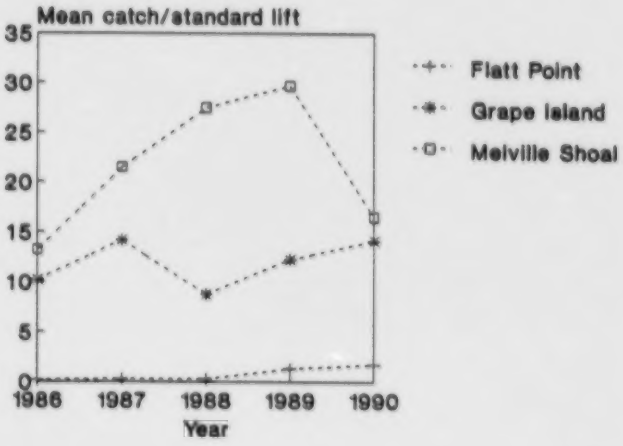

FIG. 7. Mean catches of smallmouth bass at transects in eastern Lake Ontario during July and August.

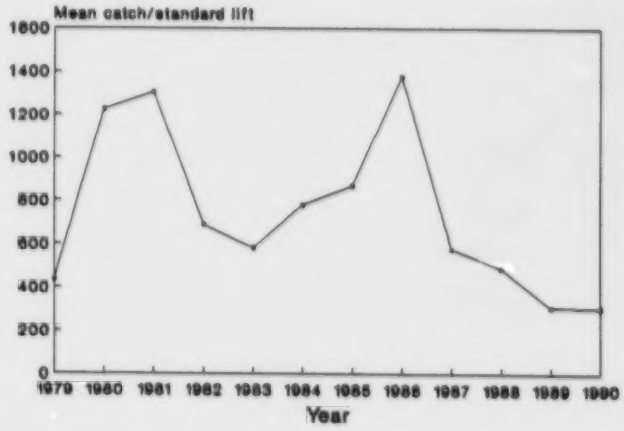

FIG. 8. Mean catches of all sizes of yellow perch at the Middle Ground site in eastern Lake Ontario during July and August.

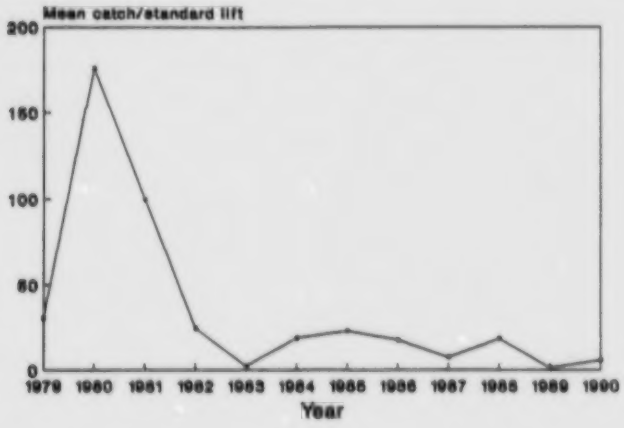

FIG. 9. Mean catches of marketable sized yellow perch (7.5 in total length) at the Middle Ground site in eastern Lake Ontario during July and August.

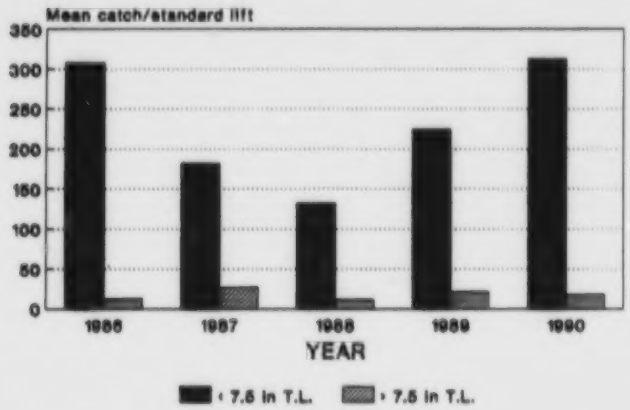

FIG. 10. Mean catches of yellow perch by size-class at eastern outlet basin sites (Platt Point, Grape Island, and Melville Shoal) during July and August.

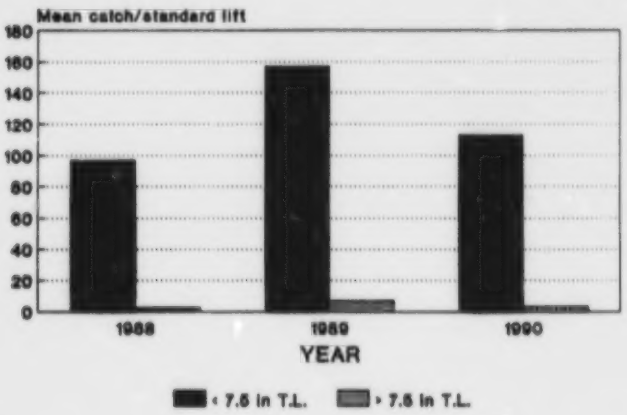

FIG. 11. Mean catches of yellow perch by size-class at central/west Lake Ontario sites (Brighton, Wellington, and Rocky Point) during July and August.

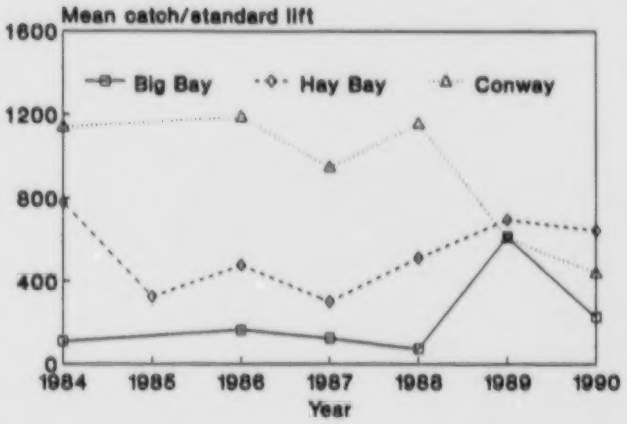

FIG. 12. Mean catches of yellow perch at gillnet sites in the Bay of Quinte, Lake Ontario during June to August.

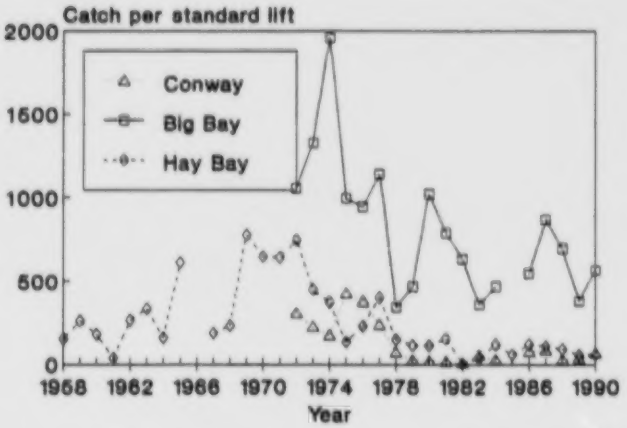

FIG. 13. Mean catches of white perch at gillnet sites in the Bay of Quinte, Lake Ontario during June to August.

Discussion

Attempting to interpret changes in fish populations over a 3 to 5 year time frame is difficult. A single strong year-class can influence catches resulting in either a dramatic increase, as a strong year-class is first recruited to the gear, or sustained decreases, as the year-class ages. Many populations show long-term cyclic recruitment patterns that could be misinterpreted in short-term studies, such as those illustrated by white perch in the Bay of Quinte (Fig. 13), and as reported for rainbow smelt in western Lake Ontario (Mathers and Stewart 1990). However, it is possible to give an interim management prognosis, based on short-term trends, that may allow managers to to anticipate relevant management actions.

Lake Herring

The prognosis for lake herring is good. Gillnet catches are comparable to those of lake whitefish which are experiencing a recovery in recent years coupled with continued reproduction and early survival (Stewart 1991a). Both lake herring and lake whitefish may be benefiting from the reduced abundance of both large smelt (Casselman et al. 1991; Mathers and Stewart 1990; O'Gorman 1989) and white perch (Hurley 1986); two species suspected of preying upon lake whitefish and lake herring larvae (Christie 1973; Loftus and Hulsman 1986; Hurley 1986). Lake herring are caught in small numbers in the Bay of Quinte commercial hoopnet fishery and a sustained recovery of this population could be beneficial to this user group. Lake herring overlap considerably with alewife in distribution (Stewart 1991b) and competition for food and space seems likely. Recurrence of an alewife winter die-off, similar to that of 1976-1977 (O'Gorman and Schneider, 1986; Ridgway et al. 1990) may be of benefit to lake herring.

Walleye

Walleye catches have increased in eastern outlet basin. Mature walleye move from the Bay of Quinte to the eastern outlet basin after spawning in spring, moving back to the Bay of Quinte in fall (Payne 1963). Several strong year-classes of walleye have occurred during the 1980's (Mathers 1991) and older fish are well represented in the winter angling harvest (Hoyle and Mathers 1991). The increase in eastern outlet basin index gillnet walleye catches is likely due to an increasing abundance of older walleye, as successive year-classes mature. Currently, walleye are rare in the eastern outlet basin summer angling fishery (Mathers 1988), but larger summer resident walleye populations could lead to the development of an eastern outlet basin angling fishery targeting on this species.

Yellow Perch

Changes in yellow perch populations are difficult to interpret. Bowlby (1990) postulated that the decline in abundance of large perch in 1989 at Middle Ground was due to movement of yellow perch away from that area. However, catches of all size-classes have remained low since 1986. Large perch have not been caught in abundance since 1981, suggesting a fundamental change in populations size and age structure. These changes could be due to increased mortality or a decrease in growth rate. Processing of available calcified tissue samples to determine age and growth of yellow perch, over the study period, would determine which effect is predominant and should be given a high priority.

Brown Bullhead

Brown bullhead catches in eastern outlet basin are very low and have not changed. It is doubtful that assessment gillnets, outside of the Bay of Quinte, are fishing areas inhabited by brown bullhead and thus are not appropriate to index this species.

White Perch

Long-term trends in catches of white perch in the Bay of Quinte (Fig. 13) suggest the population continues to oscillate at a low level following the collapse of white perch in 1978 (Hurley 1986). White perch are associated with eutrophic systems (Hurley 1986) and catches in eastern outlet basin are expected to remain low.

Smallmouth Bass

Eastern outlet basin supports an important smallmouth bass angling fishery, second only to lake trout in harvest (Mathers 1988). Index netting catches show some tendency to an increasing mean catch, but detailed analysis of age, and a longer time series, are required to interpret the changes. In this regard, the index netting provides the only available time series to document and interpret changes over time in this recreationally important fish population.

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Walleye Populations In Eastern Lake Ontario and the Bay Of Quinte, 1990

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Lake Ontario Fisheries Unit, 1990 Annual Report LOA91.1 (Chapter 19)

The "fishable" walleye population (age 2 and older) in eastern Lake Ontario and the Bay of Quinte was estimated at 954,310 fish in the spring of 1990. Walleye population size has stabilized. The 1990 year-class appears to be large. Strong year-classes produced since 1985 suggest that the sport and commercial fisheries in this area will continue to prosper over the short-term. The long-term effects of varying commercial fishery quotas and angler bag limits were simulated using an age-structured model.

Recommendations

1. Maintain the walleye mark-recapture program to monitor changes in absolute abundance of walleye which may coincide with the invasion of zebra mussel.
2. Continue to assess the stock-recruitment relationship and try to quantify natural mortality in order to improve our ability to model walleye populations.
3. Complete age interpretation of walleye sampled during 1985 to 1988 mark-recapture programs and incorporate the subsequent population analyses into the walleye model.
4. Walleye captured in the eastern basin during the Assessment gillnetting program should be aged to determine if the recent increases in catches are related to year-class strength.

Introduction

This report updates the status of walleye (*Stizostedion vitreum*) in the Canadian portion of Eastern Lake Ontario and the Bay of Quinte (Fig. 1). Commercial fishery harvest statistics, angler harvest statistics (Hoyle and Mathers 1991), and population estimates from the mark-recapture project are all incorporated into an age-structured model (Bowlby and Mathers 1989a) which was used to predict future walleye populations and their fisheries. The model was also used to simulate the effect of potential management strategies involving changes to the angler bag limits, and commercial walleye quotas.

Population Estimation Procedures

The data collected during the 1989 mark-recapture session complements data collected in previous sessions conducted during the spring and fall 1985 to 1987, and fall 1988 (Bowlby and Mathers 1989b). A single mark-recapture session was conducted, from September 8 to November 24, 1989, with 134 trapnet lifts (598 trapnet nights) of effort. Eight trapnet sites and 39% of the lifts were in the lake, while 12 sites and 61% of the lifts were inside the Bay of Quinte (Fig. 1). A total of 16,696 walleye were caught. Captured walleye were examined for marks from previous sessions. Dorsal fin ray punches unique to this session were applied to unmarked fish.

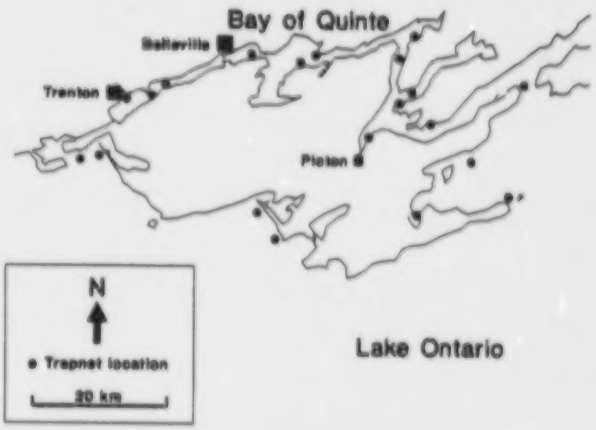

FIG. 1. Bay of Quinte and eastern Lake Ontario showing trapnet locations for the fall 1989 walleye mark-recapture project.

Age-specific walleye population estimates were made for previous sessions using the Jolly-Seber method (Ricker 1975). The size of the 1986 and 1987 year-classes were estimated using the adjusted Petersen method (Ricker 1975) since these year-classes had less than 3 recapture sessions - a requirement of the Jolly-Seber method. Fish from year-classes earlier than 1980 were lumped together and a single population estimate was made for this group.

Population estimates, for the spring of 1990, were made by subtracting harvest and natural mortality estimates from the fall 1988 estimates. Abundances of 1988 and 1989 year-classes were estimated from Research bottom trawl catches of young-of-year (YOY) fish (Bowlby and Mathers

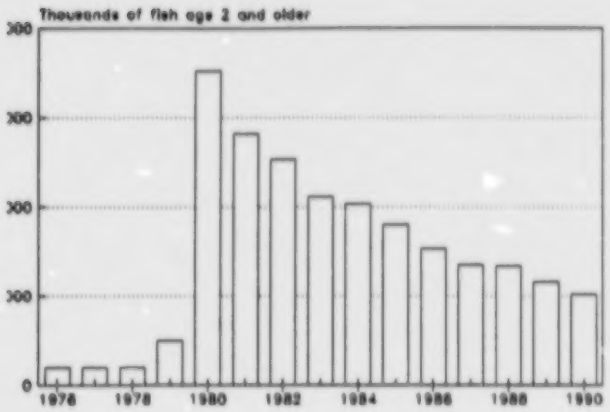

FIG. 2. Population estimates of age 2 and older Bay of Quinte walleye, during spring, for the years 1976 to 1990.

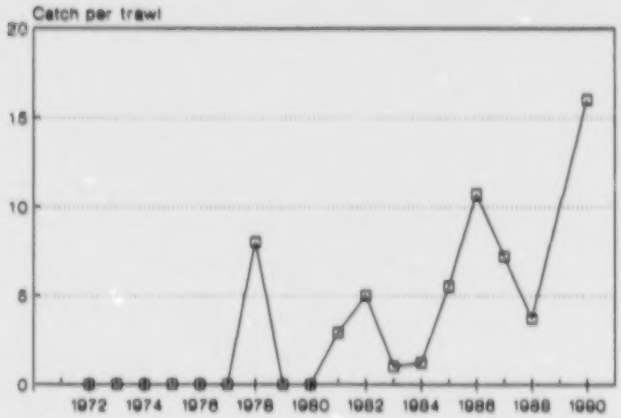

FIG. 3. Mean catch of young-of-year walleye in trawls in the Bay of Quinte during August and September, for the years 1972 to 1990.

1989b). Harvest estimates were obtained from the angling and commercial fishing surveys described in Mathers and Bowlby (1990) and Hoyle and Mathers (1991). Natural mortality, which includes mortality due to poaching, incidental catch in commercial fisheries, predation, and spawning mortality was assumed to be: 20% for 1-yr-olds, 10% for 2-yr-olds, and 25% for older fish, and was assumed to occur on March 31.

Estimates Of Walleye Population Size

Inclusion of the fall 1989 mark-recapture data resulted in moderate increases in the population estimates relative to previous estimates (Table 1)(Bowlby and Mathers 1989b). The population estimate of "fishable" walleye (age 2 and older) in eastern Lake Ontario during the spring of 1990 was 954,310 fish (Fig. 2). The population appears to have reached a state of some stability with the current harvest levels and environmental conditions. The recent population estimates do not differ greatly from the estimate of 1,000,000 walleye (age 3 and older) for 1958 which was prior to the population's decline in the 1960's and 1970's (Hurley and Christie 1977).

Generally, the population has varied between 1.0 and 3.5 million fish during the period from 1979 to 1990. The large population in the early 1980's (Fig. 2) was due to the unusually strong 1977 and 1978 year-classes. These two strong year-classes have been reduced in numbers in recent years because of natural mortality and fishing harvest. These year-classes were produced under unusual conditions (low competition and predation) and should not be expected to occur again in the near future (Bowlby et al. 1991).

LOFU index gillnet catches in Lake Ontario during the summer suggest that the numbers of walleye are increasing in the eastern outlet basin (Stewart 1991). This could be due to increasing populations in this area, however, a more likely explanation is the movement of walleye from the Bay of Quinte out into the lake. Payne (1963) and Bowlby et al. (1991) provided evidence to suggest that mature walleye move from the Bay of Quinte to Lake Ontario after spawning in the spring and then return again during the fall. The current increases in gillnet catches in Lake Ontario are probably due to the maturation (and spring movement to the lake) of the strong 1985, 1986, and 1987 year-classes. Analysis of age data collected in the gillnetting program would provide insight with regard to this hypothesis.

TABLE 1. Age-specific population estimates for the walleye population in eastern Lake Ontario and the Bay of Quinte. Estimates are based on data from the spring 1985 to fall 1989 mark-recapture sessions.

Session	Year-class									Population Age 2 and older
	1987	1986	1985	1984	1983	1982	1981	1980	1980	
Fall 1985				136,000	88,670	348,233	191,324	81,694	306,198	1,016,119
Spring 1986				136,000	64,798	227,681	86,228	59,002	413,814	987,523
Fall 1986			445,644	108,800	73,863	167,077	46,029	27,558	208,954	632,281
Spring 1987			445,644	89,563	106,657	194,997	52,161	37,844	229,416	1,156,282
Fall 1987		363,987	356,515	103,750	78,188	105,659	28,124	21,462	164,203	857,901
Fall 1988	74,928	151,533	219,482	148,872	119,513	107,798	48,934	22,487	97,247	915,866

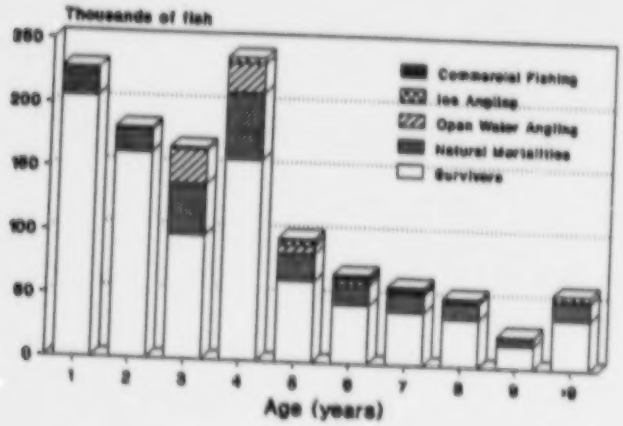

FIG. 4. Eastern Lake Ontario walleye population structure for 1990.

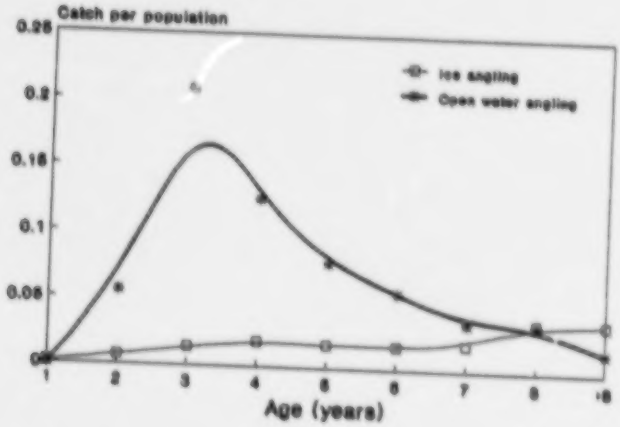

FIG. 5. Selectivity of anglers for walleye in the open water and ice fisheries in the Bay of Quinte (1988 to 1990 average). Trend lines are fitted by a moving average.

Age-Structure And Year-Class Strength

Catches of YOY walleye in the Research bottom trawling program (Fig. 3) conducted in the Bay of Quinte have been correlated with the 2-yr-old population, and are therefore assumed to provide a good index of year-class strength (Bowlby and Mathers 1989b). The age-structure of walleye present during 1990 (Fig. 4) shows evidence of the strong 1978, 1982, and 1986 year-classes detected by the YOY index. The 1990 year-class is also predicted to be strong. However, the outboard trawl program did not detect large numbers of YOY walleye this year (see Hoyle 1991 for discussion).

There appears to be a 4-yr cycle to the abundance of YOY walleye in the Research trawl series. A similar cycle has been observed in Lake Erie with peak abundances occurring in 1977, 1982, 1986, and 1990 (S. Nepszy, Lake Erie Research Station, R. R. #2, Wheatley, Ontario, N0P 2P0, pers. comm.).

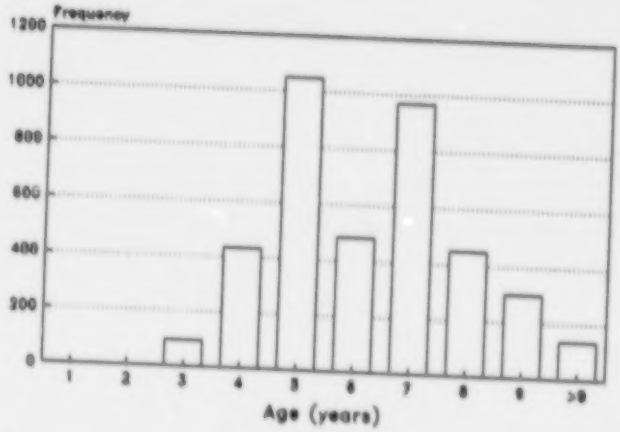

FIG. 6. Age-specific harvest of walleye during the 1989 commercial entrapment gear fishery in eastern Lake Ontario.

Angling Harvest Relative to Population Abundance

The walleye harvest during the 1990 ice angling fishery was estimated at approximately 22,500 fish (Fig. 4). During the open water angling fishery 89,955 fish were harvested (Hoyle and Mathers 1991). An angling selectivity curve was constructed by expressing the age-specific harvest of walleye from the 1988, 1989, and 1990 angling fisheries as a proportion of the population present at the time of harvest (Fig. 5). The peak of the open water selectivity curve suggests that approximately 20% of 3-yr-old fish were harvested. An earlier selectivity curve presented by Bowlby and Mathers (1989b) showed that close to 40% of the 4-yr-old fish were harvested. Lower angling effort and harvest observed in recent years (Hoyle and Mathers 1991) and the higher population estimates could have contributed to this change. The current data are similar to the previous estimates in that ice fishing has an equal impact on all age groups above 2-yr-old. Also, open water angling has the greatest impact on 3-, 4-, and 5-yr-old fish. Movement of older fish to Lake Ontario during the summer would account for their lower catch in the open water angling fishery.

Commercial Fishing Harvest Relative to Population Abundance

During 1989 and 1990 commercial fishermen were allotted a 13,789 kg (30,400 lb) quota for walleye. This followed a complete ban on the commercial harvest of walleye in Lake Ontario from 1984 to 1988. Fish were harvested in entrapment gear by commercial fishermen in quota zones 1, 2.1 and 2.2 of Lake Ontario. A "slot limit" restricted harvest to walleye between 434 to 579 mm fork length (18 to 24 inches total length), and the open season was restricted to May 1 to June 30 during 1990.

The walleye harvest reported for eastern Lake Ontario in the 1990 commercial entrapment gear fishery was 11,573 kg (25,461 lb)(D. Montgomery, Ontario Ministry of Natural Resources, 1 Richmond Blvd., Napanee, Ontario, K7R 3S3, pers. comm.) which is estimated to represent

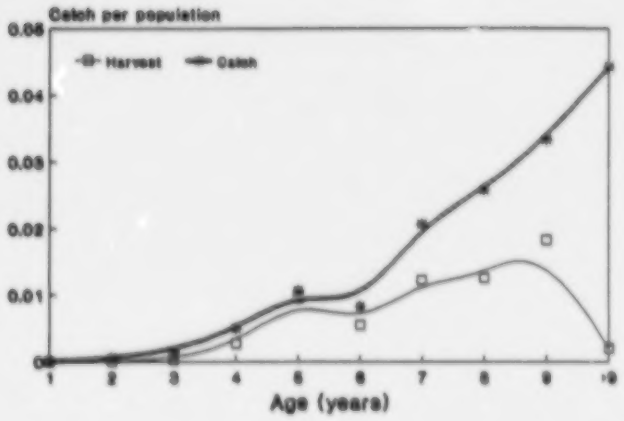

FIG. 7. Catch and harvest selectivity of walleye by the 1989 commercial entrapment gear fishery in eastern Lake Ontario. Trend lines are fitted by a moving average.

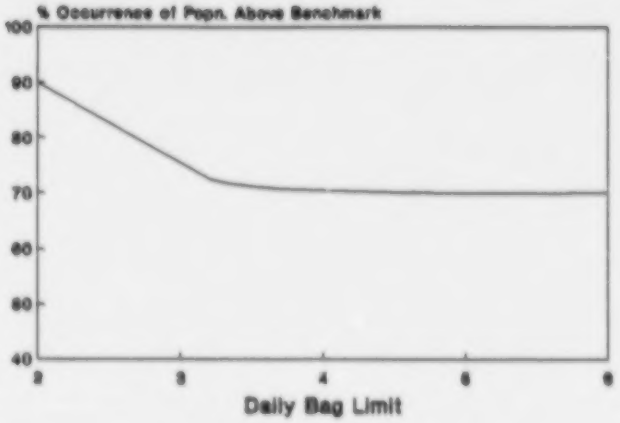

FIG. 8. Simulated effect of varying the walleye bag limit on the adult walleye population in the year 2000. Shown is the proportion of the model runs which had a walleye population above 400,000 adult fish for a range of bag limits.

5,873 fish. No biological information is available for the walleye harvested during the 1990 commercial fishery. The age-specific catch and harvest data for walleye in the 1989 commercial entrapment gear fishery were not available until this year (Fig. 6). Bowlby (1989) describes the methods used to collect these data. In 1989, few fish less than 4- and greater than 9-yr-old were harvested. The catch selectivity curve (Fig. 7) suggests that larger walleye are more easily caught in entrapment gear than small fish. This has been demonstrated previously for walleye by Laarman and Ryckman (1980). The impact of commercial harvest appears to increase with age except for the oldest fish, most of which were excluded by the "slot limit".

Mortality Estimates

The estimate of annual mortality rate (Ricker 1975) of walleye hatched before 1984 was 27%. This estimate was based on fall 1985 to 1988 Jolly-Seber estimates. This is lower than previous estimates (36 and 47%) based on 1985 to 1987 data (Bowlby et al. 1991). The decline in the annual mortality rate could be due to lower angling mortality (discussed above) or reduction in incidental catch of walleye in commercial gillnet fishery (Dentry and Boraski 1989). Also, the group being used for this analysis is aging. Mortality should decline since fish older than 5 yr are less likely to be caught in the open water angling fishery. The average rate of exploitation (Ricker 1975) due to the angling and commercial fisheries is less than 1% for 1-yr-old fish, 6% for 2-yr-old fish, 16% for fish 3- to 5-yr-old, and 8% for fish greater than 5-yr-old.

Future Walleye Populations and the Effect of Management Options

Angling effort during the Bay of Quinte open water fishery has decreased steadily since 1987 (Hoyle and Mathers 1991). Decreased annual angling yields will result if this trend continues. In such an event, managers could consider increasing walleye harvest allocations to sport or commercial fisheries because higher levels have been sustained in recent years.

The eastern Lake Ontario walleye model (Bowlby and Mathers 1989a) was updated with the new angling and commercial fishing selectivity curves and used to predict populations to the year 2000. Short-term projections suggests that the "fishable" population will climb to over 1 million fish in the next 3 yr. The main reason for this increase is the strong year-classes produced since 1985 (Fig. 3). These year-classes should continue to provide good angling and commercial fishing for at least the next 4 yr.

Long-term predictions of the model are more difficult to interpret. The heart of all such models is the stock-recruitment relationship. A wide range of year-class sizes have been produced by a relatively small range of adult populations in recent years in the Bay of Quinte (Bowlby et al. 1991). A single estimate of future populations could be calculated from an average stock-recruitment relationship; however, this would be unrealistic because of the wide variation in this relationship. When this variation was simulated and the model run many times with one set of parameters a range of outcomes was predicted. This range was quantified by comparing the adult population after a 10-yr period to a benchmark population of 400,000 fish. The model predicts that there is a seventy percent chance that the adult population will stay above 400,000 fish with current population and fishery parameters.

Several options to change the walleye harvest are available to the managers of this fishery including changing the commercial quota, and altering the angling bag limit for walleye. Changes to the angling fishery bag limit have a strong potential to affect walleye harvest in the short-term. The current bag limit is 4 walleye/d. The model predicts that if the bag limit was reduced to 3 fish/d, the angling harvest would be reduced by 9% (Mathers and Bowlby 1990). If the bag limit was increased to 6 fish/d, the angling harvest would be increased by 10%. The long-term effects of the changes to the bag limits are less dramatic (Fig. 8). When the bag limit was decreased to 2 fish/d 90% of the simulations had adult populations above 400,000 fish. In-

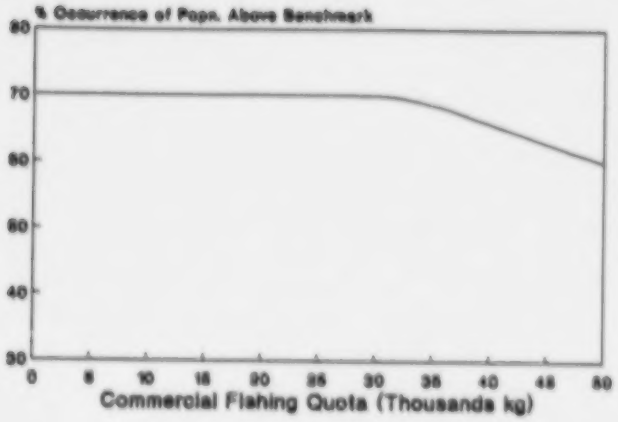

FIG. 9. Simulated effect of varying the commercial fishing quota size on the adult walleye population in the year 2000. Shown is the proportion of the model runs which had a walleye population above 400,000 adult fish for a range of bag limits.

creasing the bag limit did not have an appreciable affect on the adult population.

The 13,789 kg (30,400 lb) quota currently allocated to the commercial fishery is small relative to the population size and the other sources of mortality (Fig. 4). We estimate for 1990, that the current quota represented only 1% of the total population by number and by weight. In any one year-class, the largest mortality which can be attributed to the commercial fishery is 3%. Previous simulations (Mathers and Bowlby 1990) showed that increasing the commercial quota to 22,727 kg (50,000 lb) would not have any short-term effects on the walleye angling fishery. Long-term predictions suggest that quotas over 36,363 kg (80,000 lb) would cause an increased probability of adult populations falling below 400,000 adults (Fig. 9).

The walleye model suggests that the current management strategy provides a margin of safety. This is of particular importance now because of the potential changes in the Bay of Quinte fish community due to the zebra mussel (*Dreissena polymorpha*) invasion.

Zebra Mussel

The zebra mussel population in eastern Lake Ontario and Bay of Quinte is currently small (Schaner 1991), however, a large population is expected to develop in the near future. If the mussel population expands to the extent it has in Lake Erie, there is a strong potential for an affect on the walleye population as well as other fish species.

One potential effect is degradation of walleye spawning shoals. The Bay of Quinte walleye population spawns on rocky shoals, found both in rivers and along lake shorelines. The relative importance of the river and shoreline spawning shoals is not clear. Zebra mussel have been found to infest shoreline spawning shoals in western Lake Erie. Densities as high as 30,000 mussels/m^2 were recorded in 1989 (S. Nepszy, pers. comm.). The mussels are not thought to degrade river spawning shoals since they generally do not invade upstream. Preliminary results, from field work during 1990 in Lake Erie, suggest that walleye spawn successfully on shoals infested with large numbers of zebra mussel. As noted earlier a large walleye year-class was produced in Lake Erie during 1990 - even though zebra mussel are well established there (S. Nepszy, pers. comm.).

Another potential effect of the zebra mussel is a shift in the aquatic food chain in the Bay of Quinte. It is likely that zebra mussel will cause an increase in benthic biomass and a decrease in the planktonic biomass. This may cause an increase in water clarity and aquatic vegetation. It seems likely that these changes would lead to increases in the smallmouth bass, largemouth bass, and northern pike populations and reductions in walleye abundance.

Light is probably the most important environmental stimulus affecting walleye behavior, and changes in light intensity can cause walleye to alter their distribution (Colby et al. 1979). If zebra mussel cause a change in the water clarity of the Bay of Quinte in the future we anticipate that the walleye population could change its pattern of movements and/or feeding behavior. Changes in distribution will affect catches by all types of gear including angling, gillnets, trapnets and trawls. Anglers in Lake Erie claim that they are catching walleye in deeper water since the zebra mussel invasion. If Bay of Quinte walleye move to deeper water as zebra mussel abundance increases there would be a decrease in angling and index gillnet catches in this location. Such a change in distribution does not necessarily mean a change in walleye abundance, however, these changes would be impossible to interpret without a mark-recapture program. Therefore, maintaining the walleye mark-recapture program, to monitor changes in absolute abundance of walleye which may coincide with the invasion of zebra mussel, is recommended.

Acknowledgments

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Lake Ontario Temperature Studies

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Preliminary results of various studies to explore the use of temperature as means to stratify and interpret Lake Ontario fish community index programs are presented. Temperature distributions of fish caught in gillnets illustrates that temperature is a principal variable determining fish community structure. Lake Ontario temperature data for the years 1960 to 1990 were used to delineate unique zones of thermal structure. The probability of thermal stratification, within a zone, was related to surface water temperature. Limited available information suggested that these zones are associated with differences in both smelt and alewife abundance and smelt growth. Regional estimates of lake trout sustainable yield, based on optimal thermal habitat volume, ranged from 0.08 to 0.43 kg/ha.

Recommendations

1. Refine approaches to delineating unique thermal habitat zones in Lake Ontario.
2. Use surface water temperature to stratify lakewide fish sampling programs.
3. Determine if regional estimates of stocked lake trout survival and biomass are related to the availability of optimal thermal habitat.

Introduction

Increasingly, Lake Ontario fisheries assessment information is required on a lakewide basis, and it is important to be able to stratify the lake to develop precise, cost-effective fish community indexing programs. Effective use of habitat stratified fish community indexing designs requires an understanding of the relationship between habitat and fish distributions. Also, differences in fish community characteristics (species composition, growth, life history) are associated with differences in habitat. In 1990, a workshop was held to consider how to stratify Lake Ontario for the purpose of lakewide fish community indexing surveys. The workshop was led by Dr. Peter Sly (Rawson Academy) and attended by staff of the Lake Ontario Fisheries Unit (LOFU), Lake Erie Fisheries Assessment Unit (LEFAU), and the U.S. Fish and Wildlife Service (USFWS). The workshop concluded that temperature was a primary habitat variable by which Lake Ontario fish community indexing programs could be stratified.

Studies have shown that time-integrated volumes of water, or bottom areas, bounded by species-specific temperature optima, are correlated with species- specific sustainable yields (Christie and Regier 1988; Payne et al. 1990). These studies provide a conceptual link between temperature and productivity, and if applied on a regional scale, may delineate differing fish species assemblages.

This report provides preliminary results of studies to: (1) investigate the distribution of fish with respect to temperature, (2) delineate zones within Lake Ontario of unique thermal structure, and (3) develop regional estimates of lake trout sustainable yields based on thermal habitat volume.

Methods

Fish Distributions

Fish distributions were examined by analyzing catches from eastern Lake Ontario assessment gillnets for the years 1986-1990. These nets were fished in July and August in waters less than 30 m deep. The water temperature at the bottom of the gillnet was measured at the time of setting or lifting of the net. Details of the sampling design can be found in Stewart (1991), and reports referenced therein. The distribution of each species with respect to temperature was described as the average catch-per-unit-effort (CUE) for each 1°C temperature class. Species with low sample sizes or temperature distributions that were significantly different than normal (Shapiro-Wilk statistic, SAS UNIVARIATE procedure) were eliminated. The distributions were described by the median, tenth and ninetieth percentile.

A description of the thermal structure of Lake Ontario was developed from temperature profile data archived at the National Water Research Institute (NWRI) of the Department of the Environment (DOE), Burlington. The data represent approximately 30,000 temperature profiles obtained during spot cruises of Lake Ontario over the period 1960 to 1990.

FIG. 1. Map of Lake Ontario showing areas used to summarize temperature data.

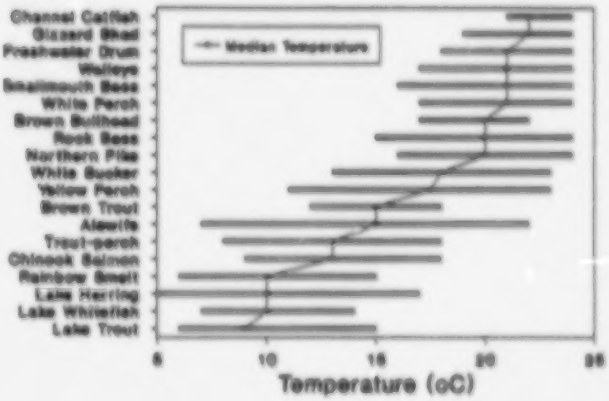

FIG. 2. Temperature distribution of fish species determined from catches of fish in gillnets in the eastern Lake Ontario over the period 1986-1990. The lower and upper temperature bounds represent the tenth and ninetieth percentile of observed temperature distributions, respectively. The line connects the median observed temperature of capture for each species.

Thermal structure descriptions were based on surface temperature, presence of a thermocline, and depth of specific isotherms. The thermocline was defined as the occurrence of a change of temperature of 1°C or more over a depth range of 1 m (Hutchinson 1957). In addition, profiles with maximum thermocline temperatures less than 10°C were considered destratified (< 1% of all profiles). Multiple thermoclines were ignored. The minimum and maximum depth of the thermocline were determined for each profile. The depth of occurrence of temperature strata at 2°C intervals was also developed for each profile.

The data were summarized based on two systems of spatial reference. The first corresponds to a 2 km^2 grid system for Lake Ontario for which a bathymetric description has been developed (Robertson and Jordan 1972) and allowed for temperature based volumetric calculations. The second was arbitrarily chosen to correspond to the division of Lake Ontario used by Mathers et al. (1991). Eight areas were identified (Fig. 1). With the exception of the eastern outlet basin (area 1), each area was further divided into two depth zones corresponding to depths from 0-40 and greater than 40 m (Fig. 1). All of the outlet basin (area 1) was considered one depth zone, as most of this basin does not exceed 40 m in depth.

For the purpose of this preliminary report, only temperature profiles for July and August were considered, as this corresponds to the most intensive period of fish community indexing activity at LOFU. Unweighted means and corresponding coefficients of variation (CV) of surface temperature, and depth of both the top and bottom of the thermocline, were determined for each depth zone, each month. The frequency of occurrence of a thermocline, over all years combined, was also determined and the relationship between the probability of stratification and surface temperature investigated.

Time-integrated water volume, corresponding to a temperature range of 8-12°C from May to October, has been shown to be highly correlated with lake trout sustainable yields (Christie and Regier 1988). A reformulation of this concept concluded that similar correlations could be obtained using only July temperature bounded volumes (Payne et al. 1990). These studies provided a means to express differences in thermal structure among areas of Lake Ontario in terms of lake trout yield. For this report we determined area-specific estimates of lake trout sustainable yields using the approach of Payne et al. (1990). The July thermal habitat volume (THV) was determined by calculating the volume of water bounded by the average depth of the 8 and 12°C isotherms. These temperatures were not apparent in some July profiles. Therefore, volumes were multiplied by the proportion of profiles with temperatures between 8 and 12°C. The resultant THV's were summed, and the relative proportion of THV contributed by each area was applied to the predictive equation reported in Payne et al. (1990), to estimate lake trout sustainable yields. The total July THV reported in Payne et al. (1990) was used in the equation, rather than the sum of the area-specific THV's calculated in this study. Yields were expressed as kg/ha for each depth zone.

Results

Fish Distributions

The temperatures distribution of fish caught in gillnets represents an overlapping continuum from warmwater to coldwater species, although clear separation of some species is apparent (Fig. 2). For example, rainbow smelt, lake herring, lake trout, and lake whitefish represent a coldwater species assemblage based on a median temperature of distribution of 10°C. or less (Fig. 2). Similarly, channel catfish, freshwater drum, gizzard shad, walleye, smallmouth bass, and white perch represent a warmwater species assemblage based on a median temperature of distribution of 21°C or greater. Alewife and yellow perch show very broad temperature distributions, and cohabit thermal strata with a variety of both warmwater and coldwater species. These data clearly illustrate that temperature is a principal variable determining fish community structure in Lake Ontario.

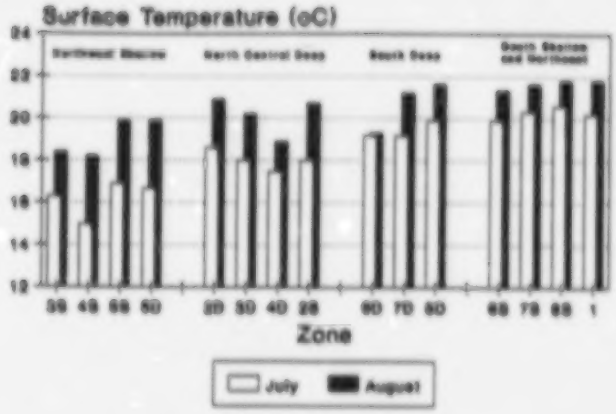

FIG. 3. Mean surface temperature for different areas of Lake Ontario. The numbers refer to the areas shown in Fig. 1. The "S" or "D" following each area number refers to shallow (≤40 m) and deep (>40 m) areas of each area, respectively.

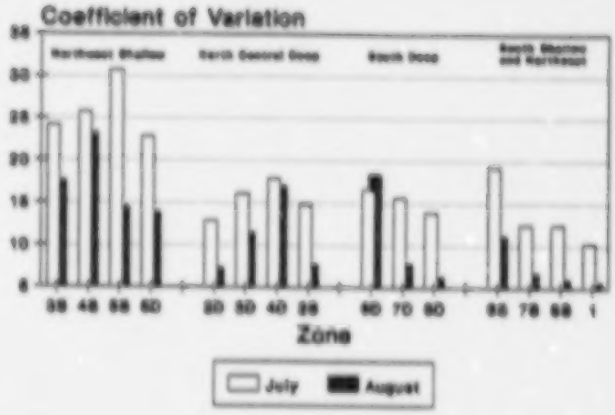

FIG. 4. Coefficient of variation of the mean surface temperature for different areas of Lake Ontario. The numbers refer to the areas shown in Fig. 1. The "S" or "D" following each area number refers to shallow (≤40 m) and deep (>40 m) areas of each area, respectively.

Thermal Structure

A total of 6824 temperature profiles were summarized for July and August. The number of profiles for each zone, each month, ranged from 72 to 514. Inspection of statistics describing thermal structure suggested a general geographic clustering of areas with similar characteristics. For clarity, clusters suggested by surface water temperatures (Fig. 3) were maintained for other variables. Mean surface temperatures in July and August increased in a general southeast direction. The coolest water is found in the shallow zones of the north shore of central and western Lake Ontario and in the deep waters in extreme western Lake Ontario (Fig. 3). Temperatures warm in either a south or east direction, and warmest temperatures are found along the shallow south shore zones and in the eastern outlet basin (Fig. 3). Cooler areas are associated with higher variation in temperature (Fig. 4), and shallower thermoclines with narrower depth ranges (Fig 5 and 6). These result strongly suggest that it is possible to delineate unique zones of thermal structure in Lake Ontario.

Thermal structure within a zone is related to surface temperature. In the shallow south shore zones and in the eastern outlet basin, water is predominately warm and mixed. For the other zones, the probability of thermal stratification is related to the surface temperature (Fig. 7). Generally, surface temperatures less than 13-15°C in July are associated with a very low probability of stratification. These results suggest that surface water temperature alone could be used to recognize areas of unique thermal structure, that in turn, may be associated with different fish assemblages.

Lake Trout Yields

Based on application of the THV yield model, regional estimates of lake trout sustainable yields range from 0.08 to 0.43 kg/ha (Fig. 8). Lowest estimated yields were in the shallow south east areas and the eastern outlet basin. While higher yields were estimated for all deep zones of Lake Ontario and shallow zones along the north shore (Fig. 8).

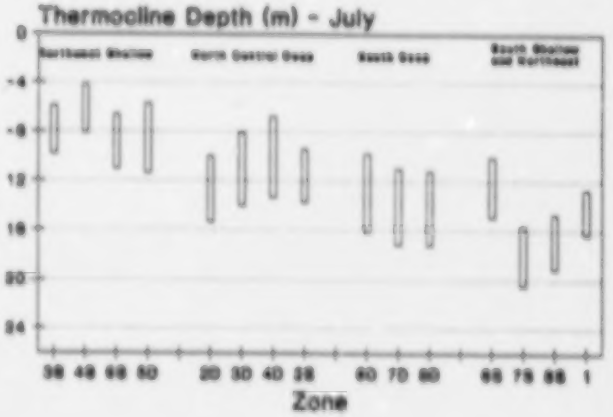

FIG. 5. Thermocline depths in July for different areas of Lake Ontario. The bars define the mean depth of the top, bottom, and extent (range from top to bottom) of the thermocline. The numbers refer to the areas shown in Fig. 1. The "S" or "D" following each area number refers to shallow (≤40 m) and deep (>40 m) areas of each area, respectively.

Discussion

Intra-lake differences in thermal structure are apparent. Similar zonations of surface water temperatures were reported by El-Shaarawi and Kwiatkowski (1977). The corresponding link to differing fish community structure has not been firmly established for Lake Ontario, however, the limited available evidence is supportive. Trawling surveys indicate that adult smelt abundance and growth are much higher in western Lake Ontario compared to the south shore (Mathers and Stewart 1990; Mathers et al. 1991). High smelt abundances were also associated with unusually cool, destratified waters, offshore from Rochester in 1990 (Mathers et al. 1991). These results suggest that cooler water temperatures may be advantageous to smelt production in Lake Ontario. Young-of-the-year alewife are found

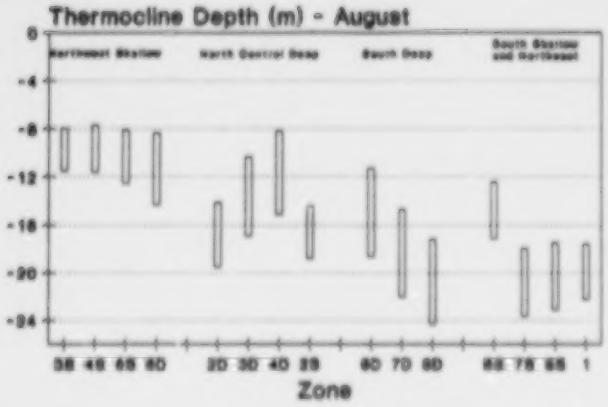

FIG. 6. Thermocline depths in August for different areas of Lake Ontario. The bars define the mean depth of the top, bottom, and extent (range from top to bottom) of the thermocline. The numbers refer to the areas shown in Fig. 1. The "S" or "D" following each area number refers to shallow (≤40 m) and deep (>40 m) areas of each area, respectively.

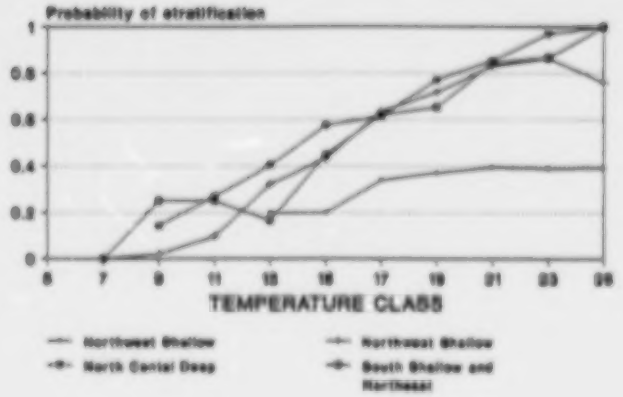

FIG. 7. Probability of thermal stratification in July for different groups of Lake Ontario areas in relationship to surface water temperature. The temperature class represents the midpoints of 2°C temperature intervals.

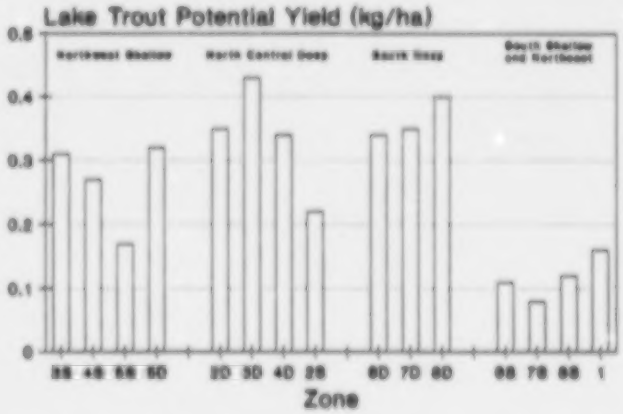

FIG. 8. Estimates of lake trout sustainable yield for different areas of Lake Ontario based on the model of Payne et al. (1990). The numbers refer to the areas shown in Fig. 1. The "S" or "D" following each area number refers to shallow (≤40 m) and deep (>40 m) areas of each area, respectively.

in warmer epilimnetic water (Brandt 1980; Mathers et al. 1991) and higher overall abundances in August were generally associated with the warmer zones identified in this study (Mathers et al. 1991). Adult alewife abundances, consistent with the broad range of temperature utilized by adults of this species (Fig. 2), did not show strong associations with the warmer zones (Mathers et al. 1991).

It is possible to stratify Lake Ontario fish community index programs based on surface temperature. Calibrated, and contoured satellite images of Lake Ontario surface temperature are available within hours of a satellite passing overhead (Offshore Services, 2679 Route 70, Mansquan, New Jersey, 08736). These could be used to stratify fish community indexing programs. Proper application of these data to fish community indexing designs will require refinement of the relationship among surface temperature, thermal structure and fish community structure. However, these preliminary results are very encouraging.

More work needs to be done to examine temporal variation, and determine the potential bias and statistical properties. A statistical approach to zonation similar to that used by El-Shaarawi and Kwiatkowski (1977) should be repeated using the additional years of data and thermal parameters described here. More definitive links between thermal structure and fish community structure can be developed by including temperature monitoring as a routine part of fish community indexing programs.

Currently, approximately 40% of all lake trout are stocked in the eastern outlet basin of Lake Ontario (Savoie and LeTendre 1991) and survival objectives for stocked lake trout have not been consistently met (Schneider et al. 1991). The low sustainable yields predicted for this area (Fig. 8), reflecting the low availability of optimum thermal habitat for lake trout, suggest that survival might be improved by a redistribution of stocking. This hypothesis should be tested by determining regional estimates of stocked lake trout survival and biomass for comparison to estimates of optimal thermal habitat. Alternatively, it may be important to stock fish in close proximity to historical shoals to increase the chances of natural reproduction. Most known historical spawning shoals are in the eastern outlet basin (Thibodeau and Kelso 1990), however, there is little current evidence of survival of naturally reproduced fry (Schneider et al. 1991). Until we better understand the spawning and site selection behavior of stocked lake trout, and better characterize and map lake trout spawning habitat in Lake Ontario, we can not offer unequivocal advice concerning stocking locations.

It may be desirable to extend the concept of optimal thermal habitat to other important Lake Ontario fish species. This may provide a conceptual framework to develop targets for a fish species mix optimizing total fish production.

We conclude from these studies that fish community indexing designs, interpretations, and fisheries management practices can be improved with an understanding of spatial variation in thermal habitat.

Acknowledgments

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Research Project: Fish Community Dynamics of the Outlet Basin of Lake Ontario

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Lake Ontario Fisheries Unit 1990 Annual Report, LOR 91.1 (Chapter 21)

Sampling of the deep-water fish community of the Outlet Basin with multifilament bottom-set gill nets and bottom trawls continued from May to August 1990 at the six standard deep-water stations. Subsampling of the gill-net catches and replicate trawling now make it possible to measure sampling variability and provide confidence limits for the catches in this long-term index series that Research has maintained and studied for 30 years. Lake whitefish and hatchery lake trout catches have increased in unison since 1982 but most markedly since 1986. Catches of these two species were at an all-time high in 1990 but were not significantly different than in 1989. The numbers of large alewife entangled in the coarse mesh of these gill nets have shown a decreasing trend since the early 1980s. In 1990 they approached the record low level of 1977. Although the tendency over the past 10 years has been for fewer and smaller smelt to be entangled in the filaments of these nets, in 1990 smelt taken this way were more abundant and larger, especially in the coarse meshes. Catches of yellow perch in the gill nets and of sculpins in the trawls were among the lowest seen during the years sampled. Catches of smelt in the trawls, generally small individuals, have steadily increased over the years, and catches in 1990 were the highest taken, although they were not significantly different than the smelt catches in the trawls in 1988. Alewife catches in bottom trawls in the Outlet Basin are variable and have shown no general trends over the years.

Background and Objectives

For the past 30 years fish sampling at the community level has been conducted each summer in the deep waters of the Outlet Basin of Lake Ontario. Commencing in 1961 this long-term index series has been conducted in a very consistent and standard fashion. Six fixed deep-water stations (26-38 m) have been sampled once a month during the summer (May-August) with multifilament experimental gill nets ranging in mesh size from 1.5- to 6-inch stretch. Since 1972 a three-quarter "Yankee Standard" No. 35 bottom trawl has been drug at six similar deep-water stations for 1/2 mile (804.7 m) for each of the summer months.

These stations and gill nets were originally selected to assess change in the lake whitefish population and to assess the contribution of alternate-year stocking of lake whitefish fry. However, over the years, it has become a long-term standard "lake" index series that Research has used to study and monitor the deep-water fish community of the Outlet Basin of Lake Ontario.

More recently this sampling has been used to study and document the response of the fish community to the reintroduction of the once-abundant, large, piscivorous keystone predator--lake trout. It also has provided the opportunity to assess the effects of changes in water quality on the fish community of the Bay of Quinte and the adjacent waters of the Outlet Basin. Special emphasis has been placed on such species as lake trout, lake whitefish, lake herring, rainbow smelt, and alewife. As data become available to evaluate and quantify sampling variability, detailed analyses of community dynamics and species interaction will be conducted.

Progress

Traditionally, only one sample was drawn at each station each month. Although the sampling effort was intensive in this long-term series, there was no measure of the observational variability for the sampling methods or the community involved. In 1988 a study of sampling variability was initiated in this sampling program. In addition to routine sampling, at each station green monofilament gill nets were fished at each station concurrently with the multifilament nets. In 1989 and 1990, in addition to the standard effort, three more 25-yard panels of each of 1.5- and 2.0-inch mesh nets were used. This meant that a total of 100 yards of each mesh size were fished. This was, however, split into two equal-sized gangs. In both 1989 and 1990 all meshes were subsampled by 50-foot intervals. This provided a total of six replicate catches (three from gang one and three from gang two) to measure the observational variability associated with these large units of gill-net effort. The results of this study of sampling variability will be reported subsequently (Casselman 1991).

Prior to 1988, one trawl drag was conducted at each station. However, in 1988 four replicate drags were made at each station. In 1989 trawling was not conducted because the vessels were being refitted. However, trawl estimates were made for smelt and alewife in 1989 by using the relationship that exists between trawl and gill-net

catches in this Outlet Basin data series. Trawling was again conducted in 1990, when three replicate drags were made at each station during each of the four months.

Although a considerable amount of data have been collected in this Research series, this report simply presents some of the more salient observations and trends in the catches. Gill-net catches are reported as numbers caught per 100 m^2 of net, and for the first time, 95% confidence limits about the geometric mean catch are provided for the more abundant species. These limits are now available for the gill-net catches for 1989 and 1990 and for the trawl catches for 1988 and 1990.

Changes in the relative abundance for the three large species that are taken most frequently in this long-term time-trend series are presented in Fig. 1. Some pronounced trends are apparent in these catches. In 1990 the catches of lake trout and lake whitefish in these gill nets were the highest that have been observed in the 30 years that the fish community has been sampled. However, they were only slightly higher and not significantly different than in 1989. It is apparent from this series that the resurgence of lake whitefish in recent years parallels the increase in lake trout numbers but appears to lag it by approximately 4 years. The August catches of lake trout showed a decrease in 1990 in comparison with 1989 and more closely approximated the August catches in 1988, which were low relative to the general trend observed of increasing lake trout numbers in the Outlet Basin in recent years. This, again, indicates that lake trout catches in late summer in the Outlet Basin underestimate the true size of the lake trout population in the Eastern Basin of Lake Ontario. During extremely hot summers, the thermocline reaches the bottom over most of the Outlet Basin in August. The lake trout move out of these warmer waters and over the Main Duck Sill into the deeper, cooler main basin of the lake and are not as vulnerable as in colder summers. This behaviour was especially noticeable during the record warm summer of 1988.

Lake herring catches were slightly lower in 1990 than in 1989 (Fig. 1), but it is unlikely that these catches were significantly different or that this indicated any significant downturn in the general trend noticed in recent years suggesting a gradual albeit slight increase in the lake herring population. Unfortunately, present catch levels are too low to calculate meaningful confidence limits for lake herring.

In contrast to the large species, which were caught in record numbers in 1990, the catches of small prey species were extremely low, especially those which have been indexed through entanglement in the relatively coarse mesh of these gill nets (Fig. 2). Independent of size, the smelt and alewife catches were not significantly different in 1990 than in 1989. The confidence limits for these catches were unexpectedly narrow (Fig. 2), especially for alewife, indicating that this index could be very useful for detecting changes in relative abundance. For the past 10 years, there has been a general decrease in trend in the number of smelt that have been entangled in these gill nets. In contrast, for the past 2 years there has been a marked upward change in this trend. When these catches are compared with the catches of large smelt and alewife entangled in the coarser meshes of these nets, it is apparent that the general trends observed in the smelt and alewife catches in this gear are almost entirely a result of the decreases

FIG. 1. Relative abundance of lake trout, lake whitefish, and lake herring in the Outlet Basin of Lake Ontario, 1961-1990, as indicated by numbers caught in experimental gill nets set 26-36 m deep. Six stations were sampled once during May, June, July, and August, and the results were averaged. Experimental gill nets were white multifilament 8 ft (2.44 m) deep, and were composed of two 25-yd (22.86-m) panels of 1.5- and 2-inch mesh and two sets of eight 50-yd (45.72-m) panels ranging from 2.5- to 6-inch mesh stretch in 0.5-inch intervals. In 1989 and 1990, all panels were 50 yards (45.72 m) long. Catches are expressed as numbers per 100 m^2 of experimental net. The 95% confidence limits about the geometric mean catch, as determined by subsampling (N = 6), are indicated for lake trout and lake whitefish for 1989 and 1990.

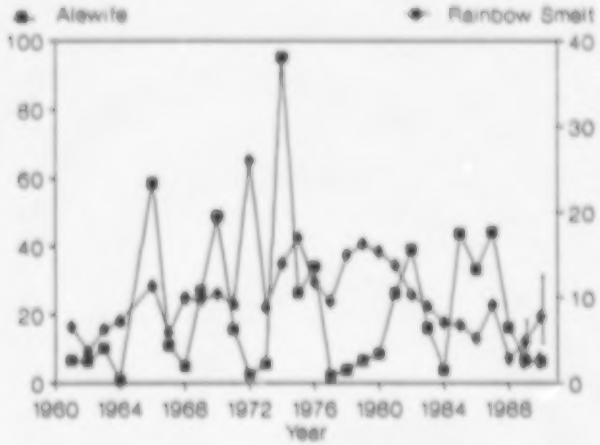

FIG. 2. Relative abundance of all sizes of alewife and rainbow smelt in the Outlet Basin of Lake Ontario, 1961-1990, as indicated by numbers entangled in experimental gill nets set 26-36 m deep. Six stations were sampled once during May, June, July, and August, and the results were averaged. Experimental gill nets were white multifilament 8 ft (2.44 m) deep, and were composed of two 25-yd (22.86-m) panels of 1.5- and 2-inch mesh and two sets of eight 50-yd (45.72-m) panels ranging from 2.5- to 6-inch mesh stretch in 0.5-inch intervals. In 1989 and 1990, all panels were 50 yards (45.72 m) long. Catches are expressed as numbers per 100 m^2 of experimental net. The 95% confidence limits about the geometric mean catch, as determined by subsampling (N = 6), are indicated for 1989 and 1990.

in the numbers of larger individuals (Fig. 3). Although confidence limits for these catches have not been calculated, it is obvious that numbers of large alewife in the deeper waters of the Outlet Basin were at an all-time low in 1889 and that the numbers of large smelt have increased

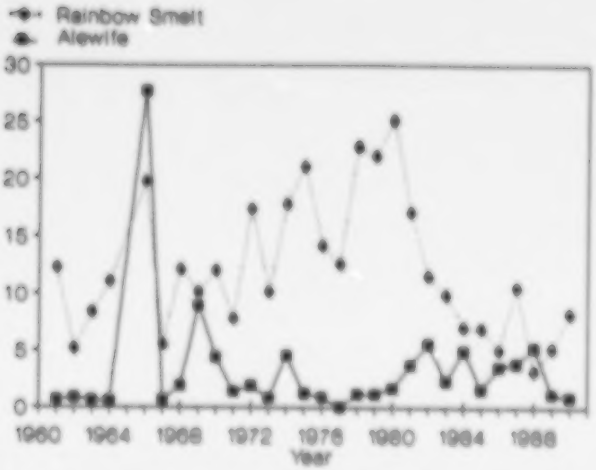

FIG. 3. Relative abundance of large alewife and rainbow smelt in the Outlet Basin of Lake Ontario, 1961-1990, as indicated by numbers entangled in selected meshes of experimental gill nets set 26-38 m deep. Six stations were sampled once during May, June, July, and August, and the results were averaged. Experimental gill nets were white multifilament 8 ft (2.44 m) deep, and were composed of two 25-yd (22.86-m) panels of 1.5- and 2-inch mesh and two sets of eight 50-yd (45.72-m) panels ranging from 2.5- to 6-inch mesh stretch in 0.5-inch intervals. In 1989 and 1990, all panels were 50 yards (45.72 m) long. Catches are expressed as numbers per 100 m^2 of experimental net. Alewife catches were fish entangled in 3.0-, 3.5-, and 4.0-inch mesh. Smelt catches were fish entangled in 2.5-, 3.0-, and 3.5-inch mesh.

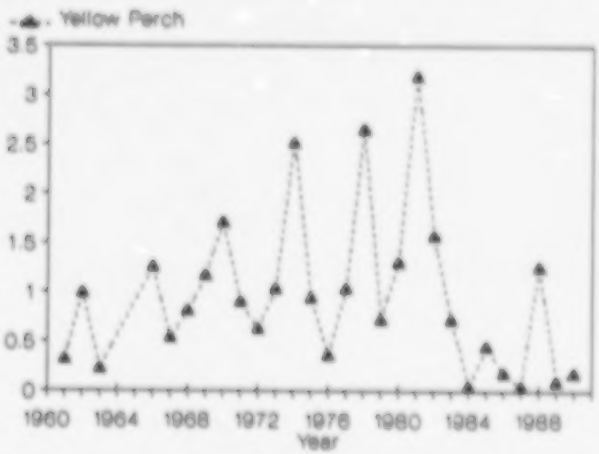

FIG. 4. Relative abundance of yellow perch in the Outlet Basin of Lake Ontario, 1961-1990, as indicated by numbers caught in experimental gill nets set 26-38 m deep. Six stations were sampled once during May, June, July, and August, and the results were averaged. Experimental gill nets were white multifilament 8 ft (2.44 m) deep, and were composed of two 25-yd (22.86-m) panels of 1.5- and 2-inch mesh and two sets of eight 50-yd (45.72-m) panels ranging from 2.5- to 6-inch mesh stretch in 0.5-inch intervals. In 1989 and 1990, all panels were 50 yards (45.72 m) long. Catches are expressed as numbers per 100 m^2 of experimental net.

slightly over the past two years from an all-time low in 1988. Lake whitefish recruitment appears to be positively correlated (with some lag) with increased lake trout abundance. It has been suggested (Casselman et al. 1990) that this may be affected indirectly through increased predation pressure on large smelt, which may prey upon larval

FIG. 5. Relative abundance of rainbow smelt and alewife in the Outlet Basin of Lake Ontario, 1972-1990, as indicated by number caught in a 1-mile (1609.3-m) tow of a three-quarter "Yankee Standard" No. 25 bottom trawl drag at depths of 26-30 m. Six stations were sampled once during May, June, July, and August, and the results were averaged. The trawl was actually drag for 1/2 mile and numbers were doubled to present as catches per one-mile tow. The trawl had a 0.5-inch cod end; however, from 1977 to 1990, with the exception of 1983, a 0.25-inch mesh liner was used. The 95% confidence limits about the geometric mean catch, as determined by replicate drags (1988--N = 4; 1990--N = 3) are indicated.

whitefish and limit whitefish recruitment. If this is the case, it may be speculated that the increase in the numbers of large smelt in the Outlet Basin of Lake Ontario in recent years may result in some decrease in lake whitefish recruitment.

Perch catches in the deep-water gill-net sets have shown a marked decrease since a high in 1981 (Fig. 4) and have been at record low levels since 1984, with one notable exception in 1988. This deviation in trend was probably caused by record high water temperatures during that summer. Yellow perch no doubt moved into deeper water and the catch with this gear increased. The decrease in yellow perch commencing in the early 1980s may be related to lake trout predation since it coincided with a significant increase in lake trout numbers (Fig. 1). However, if lake trout prey upon yellow perch, it must occur in the shallow in-shore waters because yellow perch are not observed in the stomachs of lake trout taken in these deep-water sets. The regular 4-year cycle of abundance observed up to at least 1978 (Fig. 4) indicates that strong stock-recruitment effects influence the size of this yellow perch population.

The mean catches, with upper and lower 95% confidence limits, for the four major species taken in the gill nets in 1990 are provided by station and month in Table 1.

Over the years, trawl catches of smelt in the Outlet Basin have steadily increased (Fig. 5), whereas alewife catches have fluctuated with no apparent trends. The trawl catches of smelt in the Outlet Basin in 1990 were as large as have been seen over the past 19 years. Both the smelt and alewife catches in the trawls in 1990 were not significantly different than those of 1988. Sampling variability associated with these trawls is being studied, but it is apparent that the confidence limits about the geometric mean trawl catches for these two species are

TABLE 1. The 1990 geometric mean catch (CUE) and 95% confidence limits (lower--LCL, upper--UCL) separated by station and month for four species caught in the standard white multifilament experimental gillnet ranging in mesh size from 1.5 to 6 inches fished in the Outlet Basin of Lake Ontario 26 to 38 m deep at six stations in 1990, once during each of May, June, July, and August. The confidence limits were calculated from the projected variance obtained by subsampling the catch of the standard net by 50-foot (15.24-m) intervals. The projected variance was calculated by dividing the variance of the subsamples by the square root of the effort (square root of 6--2.45). Catch of the entire net, composed of 2 x 150-foot (45.72-m) intervals of each mesh, is expressed as number per 100 m^2 of net. Sample sizes are provided.

		Alewife			Lake trout			Lake whitefish			Rainbow smelt		
Variable	N	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL
Station No.													
1[a]	4	3.8	2.6	5.8	6.5	5.8	7.3	1.2	0.9	1.7	8.6	5.9	12.6
2[a]	4	9.1	6.9	12.0	5.1	4.4	5.8	1.2	0.9	1.6	10.6	6.7	16.9
3[b]	4	7.3	5.1	10.5	7.3	6.4	8.3	0.4	0.3	0.5	8.8	7.1	11.0
4[a]	4	4.6	3.4	6.3	6.4	5.2	7.8	2.1	1.8	2.5	3.1	2.2	4.2
5[a]	4	2.8	2.2	3.7	8.7	8.0	9.4	0.5	0.3	0.8	0.8	0.5	1.2
6[c]	4	2.4	1.8	3.2	7.2	6.5	8.0	1.9	1.3	2.8	3.9	2.5	6.0
Month													
May	6	4.9	3.7	6.5	5.8	5.2	6.5	1.0	0.8	1.4	1.0	0.8	1.3
June	6	4.2	3.2	5.5	5.1	4.4	5.9	0.2	0.2	0.3	1.0	0.7	1.3
July	6	7.2	4.5	11.4	9.7	8.8	10.6	1.7	1.3	2.1	5.2	3.3	8.2
Aug.	6	3.7	2.6	5.3	6.8	5.8	7.9	1.9	1.4	2.4	16.4	12.1	22.0
Overall mean	24	5.0	3.6	7.1	6.0	6.0	7.8	1.2	0.8	1.7	6.1	3.8	9.8

[a]Approximately 30 m deep.
[b]<30m deep (approximately 25 m).

TABLE 2. The 1990 geometric mean catch (CUE) and 95% confidence limits (lower--LCL, upper--UCL) separated by station and month for five species caught in the Outlet Basin of Lake Ontario in a 1/2-mile (804.7-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at a depth of 26 to 38 m. Three replicate drags were made each month, May, June, July, and August, at six stations. Sample sizes are provided.

		Alewife			Lake trout			Lake whitefish			Rainbow smelt			Slimy sculpin			Trout-perch		
Variable	N	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL
Station No.																			
1[a]	4	1339	789	2341	9.0	5.1	15.7	2.8	0.8	9.7	4033	2157	7540	8.2	2.8	23.7	63.3	3.5	1138
2[a]	4	1569	803	3064	9.4	6.1	14.4	1.1	0.3	4.0	2837	1307	6157	8.2	1.0	67.4	4.7	0.8	26
3[b]	4	1025	367	2862	6.9	2.5	18.7	26.0	5.1	132.9	2638	1614	4312	4.5	1.2	16.3	53.6	3.5	825
4[a]	4	96	11	882	5.2	1.2	22.6	0.7	0.4	1.3	964	424	2192	3.0	0.4	20.7	9.8	1.8	54
5[a]	4	222	50	191	5.7	2.0	16.3	2.8	0.6	12.2	3010	978	9262	8.4	0.6	114.1	2.4	0.6	10
6[c]	4	2861	1176	6963	3.6	0.8	15.4	0.3	0.2	0.5	2768	1872	4094	2.6	0.4	19.2	1.1	0.6	2
Month																			
May	6	2602	482	14045	4.2	1.0	18.3	3.9	0.6	25.7	2811	936	8263	6.2	0.8	47.5	248.2	31.5	1957
June	6	330	136	803	6.5	1.7	25.6	2.2	0.5	9.3	1501	825	2732	10.6	1.1	100.7	26.4	3.1	224
July	6	1490	610	3637	5.1	2.0	13.1	2.7	0.6	11.4	3051	1850	5032	3.5	0.8	14.7	9.4	0.9	62
Aug.	6	333	58	1920	10.4	5.4	19.9	22.4	0.9	46.9	3470	1762	6835	4.0	0.5	30.5	1.3	0.4	5
Overall mean	24	1189	294	4815	6.7	2.1	21.8	7.0	0.7	74.4	2708	1330	5557	6.2	0.8	48.8	77.7	2.0	2998

[a]Approximately 30 m deep.
[b]<30 m deep (approximately 25 m).

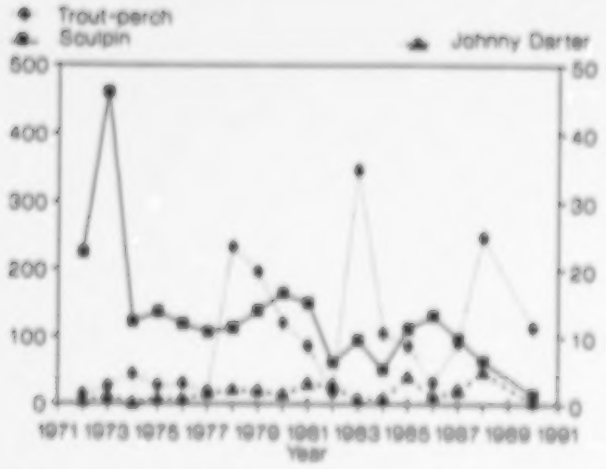

FIG. 6. Relative abundance of sculpin, trout-perch, and johnny darter in the Outlet Basin of Lake Ontario, 1972-1990, as indicated by number caught in a 1-mile (1609.3-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at depths of 26-30 m. Six stations were sampled once during May, June, July, and August, and the results were averaged. The trawl was actually drug for 1/2 mile and numbers were doubled to present as catches per one-mile tow. The trawl had a 0.5-inch cod end; however, from 1977 to 1990, with the exception of 1983, a 0.25-inch mesh liner was used. The 95% confidence limits about the geometric mean catch, as determined by replicate drags (1988--N = 4; 1990--N = 3) are indicated.

extremely large. The 95% confidence interval about the geometric mean trawl catch of alewife was approximately 11 in 1988 and 4 in 1990, and for smelt approximately 5 in 1988 and 2 in 1990.

Catches of sculpins in the trawls have shown a steady downward trend for the past 19 years (Fig. 6). Indeed, the catches in 1990 were the lowest observed. However, given the size of the confidence limits, the 1989 and 1990 catches were not significantly different. During these two years, mean catches of sculpin in replicate drags had similar confidence intervals (approximately 8).

The mean catches, with upper and lower 95% confidence limits, for the five major species taken in trawls in 1990 are provide by station and month in Table 2.

Future Directions

Subsampling to determine the relationship between observational variability and catch associated with the sampling procedures and fish community sampled in this long-term Research series was completed in 1990. The results are currently being analyzed and will make it possible to apply confidence limits and to evaluate the significance of trends observed in this community over the past 30 years.

In 1991 sampling effort will be altered and decreased somewhat. Fewer stations will be sampled so that a comparative study can be conducted between multifilament and monofilament gill nets. Three stations will be used. They will be sampled with the same amount of effort with the multifilament nets. This, however, will be conducted over two days. Each day an equal amount of monofilament gill net will be fished to make the comparison. The monofilament net that will be used will conform to the new Lake Ontario monofilament gill-net standard. This comparison will be conducted so that in the future catches in the monofilament gill nets that will become the new Lake Ontario standard can be directly related to catches in the old traditional multifilament gear that was used throughout the years in this long-term Research series. Six replicate trawls will be conducted at each of these three stations to determine whether sampling variability in the trawls can be reduced by replication. Replication and subsampling will remain an important part of this research sampling program. Fifty-foot subsamples will continue to be drawn from both types of gill nets.

In 1992 Research's traditional role of index sampling the Outlet Basin and the Bay of Quinte will be formally transferred to Assessment. Research will then focus more specifically on sampling problems, species interaction and process studies, and analyses of these long-term data sets. Special emphasis will be placed on examining the validity of age assessment and developing appropriate techniques so that accurate ages can be obtained to determine year-class strength for lake whitefish and lake herring as well as smelt, alewife, and sculpins. A detailed analysis of species interaction in this long-term data set beginning with lake whitefish will commence as soon as valid age interpretations are available now that sampling variability has been quantified and correlated with the size of the catch (Casselman 1991). One of the first hypotheses to be tested is that lake trout predation has altered the size and age structure of the smelt population and that this, in turn, has had a positive effect on the survival and recruitment of larval lake whitefish.

Scales of lake whitefish collected over the years are being used to examine long-term changes in growth and production. Otoliths are being examined in an attempt to corroborate ages interpreted from the scales and to study the stock origin of lake whitefish to determine what proportion of lake whitefish in the Outlet Basin of Lake Ontario in mid-summer belong to the "bay" and "lake" stocks.

Acknowledgments

We wish to thank the many summer students, technicians, and biologists who, over the years, have made this long-term data set possible. Most recently they were Dave Jeffrey, Dale Dewey, Steve Lawrence, Wayne Miller, Dawn Walsh, and Chuck Wood. Kelly Sarley and Ken Scott have done an excellent job of computerizing and validating all the data. Linda Balsillie, (L.O.F.U.) and Gail Coville (Brockville District) kindly worked the report into final Ventura form.

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Research Project: Fish Community Studies of the Bay of Quinte

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Multimesh gillnets have been set in sections of the Bay of Quinte annually since 1958. Measures of variance from replicate sampling in 1989 and 1990 showed significant changes in abundance for alewife and walleye. Other species have yet to be examined. Bottom trawl drags have been made since 1972 at several locations in the bay. Replicate trawl drags in June and August show a relatively large (20-40%) coefficient of variation for most species encountered. Lower coefficients (5-15%) are usually associated with large catches of alewife, rainbow smelt, white perch, yellow perch, and trout-perch. In the case of gillnets, studies to examine the effects of mesh type, hanging ratios, and net depth are planned for 1991. A change from multifilament to monofilament nylon will require extensive net calibrations.

Studies Using Multimesh Gillnets

The use of multimesh gillnets (38 to 127 mm stretched mesh in 13 mm increments) of lengths from 22.8 to 47.7 m began at one site in the Bay of Quinte in 1958 as a tool to assess fish populations and their trends through a time series. Nets were fished at one specific site in Hay Bay, situated approximately midway in the length of the Bay of Quinte, on several occasions overnight in the open water season. Beginning in 1972 as part of the increased surveys connected with Project Quinte, up to seven sites were fished monthly with this same gear each year until 1980 when the program was reduced to fishing at only three sites in the bay.

Significant alterations in the methodology are planned over the next 2 yr largely necessitated by the switch from multifilament nylon mesh to monofilament mesh. Efforts will be made to calibrate these two types of gear such that conversion indices will be available to relate one series to the other. Measures of variance derived from repeated sampling with the same gear was reported in this series for 1989 (LOA 90.1, Chapter 15). This work was expanded in 1990 and some of the results for that series are reported here.

Initially, the results of the 1990 series are reported in the same fashion as the historic series was, namely as arithmetic means of all net sets in a particular location. Big Bay in the shallow (mean depth 3.2 m) upper bay represents the more eutrophic section of the Bay of Quinte and tends to be warmer than the other sections. Hay Bay represents the middle section of the Bay of Quinte and although it is also shallow (mean depth 1.9 m), incursions of cold Lake Ontario water regularly cause dramatic drops in temperature over short periods of time. Conway is located near the lower end of the Bay of Quinte where the mean depth is 23.8 m. However, the gillnets were set across contours so that the mean depth of the net was about 15 m.

Mean catches in 1990 follow fairly closely the pattern seen in the last 4 yr (Table 1). Alewife numbers at Big Bay continue to decline as they have since 1986. Freshwater drum have increased at Big Bay as have brown bullhead. All the other species show little consistent change. Hay Bay catches in 1990 show no major trends with the exception of increased numbers of gizzard shad since 1988. Similarly at Conway, catches have not altered significantly in 1990 with the exception of a continuing fall in yellow perch numbers in both 1989 and 1990.

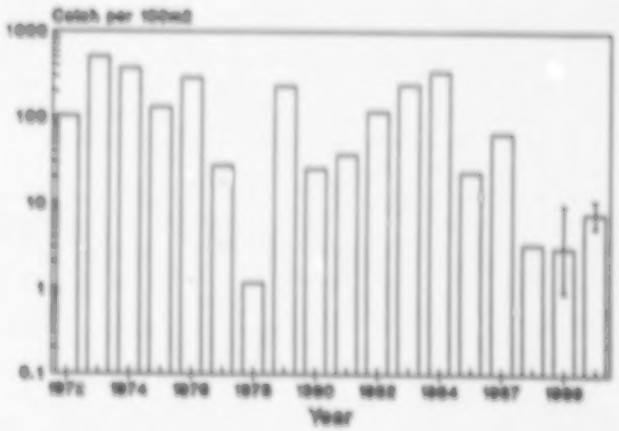

FIG. 1. Alewife catch per 100 m^2 of standard gillnet meshes in June at Big Bay. No data available for 1985. 95% confidence limits are shown for 1989 and 1990 data.

In order to measure variance of the catches, each 47.7 m section of each mesh size was partitioned vertically into six 8 m sections using coloured twine. The catch from each partition was counted and weighed separately so that the mesh sizes were replicated six times in one overnight set. This procedure was repeated twice in late June and again in late August at each of the three standard sites plus an additional one at Deseronto near the confluence of the upper and middle sections of the Bay of Quinte.

All catches were prorated to 24 hr sets and calculated on the basis of 100 m^2 of the complete range of mesh sizes used. The catches were log transformed to give a geometric mean and 95% confidence limits were calculated for both the June and August series in each location (Table 2). With these data and those calculated from 1988 and 1989 replicates, the historic series can be examined to see how the changes in abundance of species appears when confidence limits are added. One excellent example that illustrates the dramatic change in species abundance is the alewife numbers taken in June at Big Bay (Fig. 1). These alewife would represent spawners that had recently entered the bay from Lake Ontario. Large numbers of alewife were taken from 1972 to 1976. There was a dramatic decline in 1977 and especially in 1978. Alewife rebounded again in 1979 and were abundant until 1988. Since then, their numbers have remained relatively low. If the confidence limits were approximately the same throughout this series, there is strong evidence that alewife numbers have experienced statistically significant increases and decreases on a regular basis. Ridgway et al. (1990) postulated that predation by large alewife and by walleye is now controlling alewife recruitment in the bay. The August series further illustrates the declining alewife population, especially since 1987 (Fig. 2).

Walleye catches at Big Bay in the 1972-1990 period also show significant changes (Fig. 3). Very few walleye were taken until after a big year-class developed in 1978. The effects of subsequent year-classes in 1982 and 1986 can be seen in the increased gillnet catches in following years. This gear appears to be quite sensitive to the effects of large year-classes among walleye.

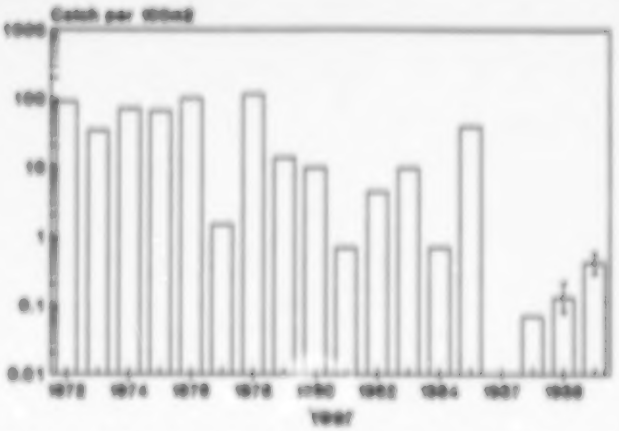

FIG. 2. Alewife catch per 100 m^2 of standard gillnet meshes in August at Big Bay. No data available for 1985. 95% confidence limits are shown for 1989 and 1990 data. No alewife were caught in 1987.

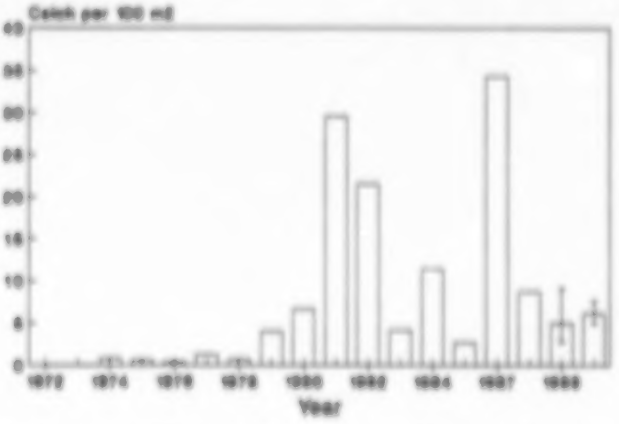

FIG. 3. Walleye catch per 100 m^2 of standard gillnet meshes in June at Big Bay. No data available for 1985. 95% confidence limits are shown for 1989 and 1990 data.

Bottom Trawl Series

R.V. Namaycush was available again in 1990 to carry out bottom trawling. No trawling was possible in 1989 while this vessel was undergoing a refit. The trawl used in 1990 was the same one that had been in use in previous years. Its measurements are: 19 m long with 6 m wings and 1.3 cm stretched mesh in the cod-end. During a standard 6 min trawl at 1.1 m/sec the net sweeps an area of approximately 0.25 ha. All data are converted to express the catch per ha. Six replicate trawl drags were made in each of four locations (Big Bay, Deseronto, Hay Bay, Conway) in mid June and again in late August. Each catch was separated by species, a total count and weight was recorded and subsamples were retained for individual lengths, weights, sex identification, scale samples (or other bony tissue), and stomach analysis. Catch data were log transformed to calculate a geometric mean and the reported values are these back-transformed numbers. The coefficient of variation was calculated for each location and time and is shown in Tables 3,4,and 5. The 95% confidence intervals were also calculated but are not shown. Overlaps of these ranges from one series to another was regarded as a non-significant difference in means.

In the upper Bay of Quinte at Big Bay, the only significant change between 1989 and 1990 was the reduction in gizzard shad in the August series (Table 3). The pattern of no alewife in the June samples continues a trend observed over several years. Ridgway et al. (1990) proposed walleye predation as the major reason for low alewife numbers in early summer. Young-of-the-year (YOY) alewife made up the entire catch in late August.

At Hay Bay, the June samples showed a significant reduction in alewife and significant increases in yellow perch and white perch between 1989 and 1990 (Table 4). Increases were recorded in the August series for alewife, white perch and walleye. YOY were preponderant in the samples in each case. There were reductions in the numbers of gizzard shad and trout-perch.

The catches at Conway were considerably different from the other stations. The proximity to Lake Ontario,

the greater depth (22 m) compared to the other stations (5 to 7 m) and much colder water at Conway all contribute to a different fish assemblage. For example, large numbers of alewife were taken in June at Conway (Table 5). The length frequency of the samples showed two distinct peaks, one at 80 mm which are the yearling fish, and another at 130 mm which are the adults. The June samples in the 2 yr showed reductions in the numbers of lake trout, lake whitefish, white sucker, trout-perch, and walleye between 1989 and 1990. In contrast, the 1990 series in August showed significant increases in numbers of alewife, white sucker, and yellow perch and no significant reductions.

Efforts will be directed towards understanding the reasons for the shifts in numbers between years and sampling seasons. The value in replicate sampling has become evident since we now are able to distinguish significant changes in abundance.

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TABLE 1. Mean catch per standard gillnet lift in the Bay of Quinte.

Big Bay

Species	1986	1987	1988	1989	1990
Longnose gar	0	41.5	14.0	7.0	33.6
Alewife	422.5	178.0	43.3	53.9	48.1
Gizzard shad	10.5	22.5	143.7	24.7	18.6
Bullhead	43.0	62.0	40.3	57.5	127.8
Channel catfish	14.5	31.0	29.7	5.7	13.5
White sucker	29.9	26.5	25.3	57.4	55.1
Northern pike	5.0	5.0	3.7	4.5	1.5
Pumpkinseed	0.5	0.5	0.3	0.5	2.5
Smallmouth bass	6.0	2.0	8.7	3.5	0.5
White perch	482.0	713.0	696.7	440.9	570.4
Yellow perch	163.5	123.0	72.0	614.8	221.5
Walleye	35.0	110.0	82.3	59.5	57.1
Freshwater drum	32.5	35.0	41.3	50.7	110.8

Hay Bay

Species	1986	1987	1988	1989	1990
Longnose gar	0	0	0	0.2	0
Alewife	249.0	191.5	929.3	194.0	140.3
Gizzard shad	2.5	2.5	218.0	47.2	66.2
Lake trout	0	0	0.7	0	0.5
Bullhead	45.5	16.5	18.0	12.0	23.6
Channel catfish	1.5	0	4.5	1.5	8.0
White sucker	7.0	23.5	10.7	15.4	11.0
Northern pike	1.0	5.5	1.3	3.7	1.5
Pumpkinseed	1.0	0.5	2.0	5.9	2.0
Smallmouth bass	7.5	4.0	0.7	6.7	3.5
White perch	99.5	83.5	93.0	72.0	62.2
Yellow perch	478.0	300.5	514.0	699.0	646.1
Walleye	49.5	13.5	25.7	46.5	35.1
Freshwater drum	23.5	7.01	6.7	17.7	13.1

Conway

Species	1986	1987	1988	1989	1990
Longnose gar	4.5	0	0	0	0
Alewife	808.0	738.5	385.9	202.0	339.9
Gizzard shad	0.5	0	20.0	9.4	11.0
Lake trout	11.5	4.5	34.0	47.7	45.1
Bullhead	1.0	0	0	0	0
Channel catfish	0	0	0.8	0.7	0
White sucker	50.5	127.0	78.3	67.2	90.7
Northern pike	0.5	0	0.5	0	0.5
Pumpkinseed	1.5	0	3.0	0	0
Smallmouth bass	4.0	1.0	15.8	6.8	9.5
White perch	59.0	70.5	26.7	40.5	66.7
Yellow perch	1189.0	947.0	1155.7	610.5	440.6
Walleye	78.5	23.5	30.5	27.4	26.1
Freshwater drum	1.0	0	50.8	20.8	6.0

TABLE 2. Geometric means and 95% confidence limits for gillnet catches at stations in the Bay of Quinte 1990. Data expressed as number per 100 m² of standard multifilament and multimesh set.

Location & Species	June 1990			August 1990		
	G Mean	L1	L2	G Mean	L1	L2
Big Bay						
Alewife	7.6	5.3	10.8	0.4	0.3	0.6
Gizzard shad	0.5	0.4	0.8	1.6	1.1	2.3
White sucker	6.2	4.9	7.8	3.4	2.2	5.3
Bullhead	7.7	6.4	9.3	7.5	2.9	19.1
Channel catfish	0.6	0.4	1.0	1.4	1.0	1.9
White perch	33.4	23.8	46.9	62.5	43.8	89.1
Yellow perch	34.9	30.7	39.8	9.3	7.5	11.6
Walleye	6.2	5.0	7.6	4.1	2.8	6.1
Freshwater drum	8.0	6.2	10.3	12.2	9.8	15.4
Napanee						
Alewife	48.8	40.1	59.5	0.2	0.1	0.3
Gizzard shad	0			3.6	1.9	7.0
White sucker	5.5	4.2	7.2	2.0	1.5	2.8
Bullhead	0			10.3	8.3	12.8
Channel catfish	0			0.7	0.5	1.0
White perch	1.6	1.0	2.6	19.8	16.9	23.3
Yellow perch	80.0	67.1	95.4	20.1	15.1	26.6
Walleye	10.2	7.5	13.9	7.8	6.3	9.5
Freshwater drum	0			6.7	5.1	8.7
Hay Bay						
Alewife	10.9	3.9	30.7	0.1		
Gizzard shad	0			10.4	7.8	13.8
White sucker	1.5	1.0	2.5	0.1		
Bullhead	0.4	0.3	0.5	2.6	1.4	4.7
Channel catfish	0			1.1	0.7	1.6
White perch	1.7	1.1	2.6	8.0	5.2	12.2
Yellow perch	67.6	53.1	86.1	32.9	47.2	59.3
Walleye	2.6	1.4	4.7	2.3	1.5	3.5
Freshwater drum	0			2.0	1.5	2.6
Conway						
Alewife	39.5	25.0	62.3	11.1	6.4	19.3
Gizzard shad	0			1.3	0.7	2.1
Lake trout	6.3	4.6	8.8	1.0	0.6	1.8
Brown trout	0			1.4	0.8	2.3
Lake whitefish	0.7	0.6	0.9	0.1		
White sucker	7.0	5.6	8.8	13.5	9.8	18.6
White perch	1.6	0.8	3.1	6.8	4.0	11.8
Rock bass	0.5	0.4	0.8	3.1	1.9	6.8
Smallmouth bass	0			1.3	0.8	2.0
Yellow perch	8.8	2.9	26.7	52.1	38.2	71.0
Walleye	1.4	0.8	2.5	2.1	1.5	2.9
Freshwater drum	0			0.7	0.5	1.1

TABLE 3. Geometric mean bottom trawl catch per hectare at Big Bay in June and August 1988 and 1990 with coefficients of variation calculated from replicate trawls.

	June				August			
	1988		1990		1988		1990	
Species	GM	CV%	GM	CV%	GM	CV%	GM	CV%
Alewife	0	-	0	-	45.8	41.1	529.2	4.1
Gizzard shad	0	-	0	-	3687.1	3.1	247.3	23.9
Trout-perch	0	-	6.0	62.1	15.4	36.6	0	-
Spottail shiner	0	-	4.1	85.0	5.9	59.4	12.6	.0
White perch	4.4	87.5	27.5	21.8	226.3	22.9	50.9	18.9
Yellow perch	5.1	2.2	14.4	40.4	0.9	56.2	1.5	12.1
Walleye	8.5	27.2	8.6	20.4	9.1	71.0	11.1	19.8

TABLE 4. Geometric mean bottom trawl catch per hectare at Hay Bay in June and August 1988 and 1990 with coefficients of variation calculated from replicate trawls.

	June				August			
	1988		1990		1988		1990	
Species	GM	CV%	GM	CV%	GM	CV%	GM	CV%
Alewife	1362.9	7.3	5.3	83.2	26.9	74.4	10068.8	8.2
Gizzard shad	0	-	0	-	708.9	16.7	34.1	32.7
White sucker	3.2	80.3	1.2	155.6	18.7	17.5	6.5	4.1
Carp	0	-	0.3	244.9	3.7	52.4	7.9	26.9
Trout-perch	10.4	82.6	34.0	18.9	118.9	10.4	2.3	18.0
Bullhead	0	-	0	-	30.7	17.2	41.8	13.3
Spottail shiner	0.7	154.9	3.3	84.7	95.6	11.8	69.6	17.6
White perch	0	-	99.3	19.4	183.9	6.8	1528.5	7.2
Yellow perch	4.5	53.6	28.2	20.4	71.4	20.7	181.6	11.0
Walleye	49.0	21.3	11.9	40.5	25.9	6.6	176.9	8.2

TABLE 5. Geometric mean bottom trawl catch per hectare at Conway in June and August 1988 and 1990 with coefficients of variation calculated from replicate trawls.

	June				August			
	1988		1990		1988		1990	
Species	GM	CV%	GM	CV%	GM	CV%	GM	CV%
Alewife	11871.9	5.8	3431.2	15.7	0	-	50.8	40.0
Rainbow smelt	3798.1	11.9	2257.4	10.5	2.4	111.2	0.9	157.6
Lake trout	6.8	33.9	0.3	244.9	0	-	0	-
Lake whitefish	126.8	10.8	3.0	84.1	8.5	27.2	12.3	51.0
White sucker	4.8	80.6	0	-	0	-	104.5	24.0
Trout-perch	124.2	8.5	5.6	72.1	559.1	12.2	757.8	3.7
Yellow perch	173.2	10.1	0	-	7.7	56.2	121.9	4.6
Walleye	15.3	22.9	0.7	154.9	8.7	71.0	19.1	25.5

Research Project: Variability Associated With Sampling the Fish Community of the Outlet Basin of Lake Ontario

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Variability is being examined for gill net and trawl sampling that has been conducted by Research to index the deep-water fish community of the Outlet Basin of Lake Ontario. This has been done by subsampling by 50-ft intervals the gill-net catches in 1989 and 1990 and by making replicate trawl drags four times at each site in 1988 and three times at each site in 1990. A detailed analysis of the catch data is being conducted so that the significance of changes in the catches over the past 30 years can be quantified. A simple compilation of the catch data is provided here to examine observational variability as reflected by the coefficient of variation for the four most frequently caught species (lake trout, alewife, rainbow smelt, and lake whitefish) in the gill nets. Sampling variability was extremely low for lake trout (3.6%) and highest for lake whitefish (21.7%), average 12.9%. Sampling variability was not significantly different between 1989 and 1990 but was significantly different at some stations and during some months. Sampling variability for both the gill nets and trawls was significantly but negatively correlated with the size of the catch for the species that were captured most frequently. Predictive regressions using the logs of these two variables were calculated. Variability in trawl samples was high; for the four species most frequently caught, it was 3.8 times greater than in the gill-net samples (average CV = 49.5%). The average sampling variability was virtually identical for rainbow smelt in these two sampling gears. For all other species, it was lower in the gill nets and higher in the trawls. This is predictable, since trawls sample younger fish, which have a greater sampling variability. The 95% confidence interval about the geometric mean catch for these four species ranged from 1.1 to 1.6 for the gill nets and 3.3 to 7.9 for the trawls. The confidence limits about the mean catch for the trawls were so broad that there was no significant difference among the catches of the five most frequently caught species, among either the six stations or the four months.

Background and Objectives

Over the past 30 years, Fisheries Research has routinely sampled the fish community of the Outlet Basin of Lake Ontario. Sampling has been consistent and extremely intensive but has usually involved only large, single units of fishing effort. In recent years, 3,000 feet (914.4 m) of multimesh bottom-set gill nets (8 ft [2.44 m] deep) have been fished at six stations for each month during summer. Trawling has consisted of a single 1/2-mile (804.7-m) drag at each station for each of the summer months. The particulars concerning gill netting and trawling have been described (Casselman et al. 1991).

The purpose of this project is to measure and examine variability associated with sampling the fish community of the Outlet Basin of Lake Ontario so that the significance of relative changes in the gill-net and trawl catches can be determined. The study is being conducted to measure the specific observational variability associated with this long-term data set and the deep-water fish community of the Outlet Basin. It has been designed to examine this variability in relation to species, fish size, site, depth, season, and type of gear. It is intended to determine whether there is a relationship between variability and size of the catch to see if it is possible to hindcast the variability and measure the confidence limits associated with previous sampling in this data set, which extends over 30 years.

Although variability has been variously measured and compared in the past 3 years, the primary method is to use subsampling for the bottom-set gill nets and replication for the bottom trawls to measure and, in the case of gill nets, to project sampling variability. During the summers of 1989 and 1990, the large panels of gill nets were subdivided into 50-ft intervals. Two gangs of nets were set at each site, each composed of 50-yd panels of each mesh size in graded series ranging from 1/2 inch to 6 inches with the fine mesh on the second net attached to the coarse mesh on the first. This meant that three 50-ft intervals of each mesh were fished in the first net and an additional three in each mesh size of the second net, for a total of six. For analysis, the catches of the first 50-ft unit of each mesh were combined and compared with the catches of the second 50-ft unit, as was the third. The fourth, fifth, and sixth units came from the second net.

The combined catches of these 50-ft subnets were treated as replicates and were used to calculate the observational sampling variability. The observational variability was projected for the entire net by estimating the variability of these subsamples of the catch. The projected observational variability of the entire net was calculated by dividing the variability determined for the 50-ft subnets by the square root of 6 (2.45), since the full net is six times larger than the subnet. This extrapolation can be performed because the reduction in sampling variability would be roughly proportional to the square root of the effort.

Ideally, observational variability would be determined by replicate sampling. However, that would be impractical for this program because of the large amount of effort already applied. True multiple replication in this gill-net series would be costly, destructive to the fish population, and difficult if not impossible to conduct in comparable time and space. Although the subsampling procedure used here has some drawbacks when compared with true replication, it is the only practical approach that can be used to provide a reasonable estimate of sampling variability under this extensive sampling regime. It is obvious that the 50-ft subsamples are not entirely comparable because of the position of the subsampled mesh in relation to other meshes. However, with the current subsampling design, this effect, which exists in all graded gill nets, could be measured, and the influence of adjacent mesh sizes on the catch could be quantified. Finer mesh and similar-sized mesh were adjacent to the first and fourth 50-ft subunits (except for 1 1/2-inch mesh, which followed no mesh in gang one and coarser mesh in gang two respectively). Similar-sized meshes were on either side of the second and fifth subunits, and similar-sized mesh and coarser mesh were adjacent to the third and sixth subunits (except for 6-inch, which was followed by finer mesh in gang one and no mesh in gang two respectively). Each of the six replicate subnets represented a graded series of meshes 1 1/2- to 6-inch stretch and 371.6 m^2 of gillnet effort.

Observational variability for the trawling was measured by replicate drags. During the summer of 1988, four replicate half-mile (804.7-m) drags were made at each station, whereas in 1990, three were made.

Sampling variability for each species was measured by adding 1 to the catch to eliminate 0 values. Then the catch data were log-transformed to calculate the coefficient of variation (CV--%). Catches were usually expressed as geometric means obtained by subtracting 1 from the antilog of the mean of the log-transformed data.

This report describes some of the cursory observations made during an initial summary of data collected during the two years of sampling.

Progress

Replicate Subsampling of Gillnets

The projected observational variability about the geometric mean catch, expressed as coefficient of variation separated by month and season for four species that were caught most frequently in the bottom-set gill nets, was quite low and was not significantly different in 1989 and 1990 (average CV: alewife--11.5; lake trout--3.6; lake whitefish--21.7; rainbow smelt--14.8) (Table 1). Sampling variability for lake trout is exceptionally low for bottom-set gill nets. However, this would be expected, given the size of the lake trout population and the amount of gill net used. The sampling variability for the other three species was higher but still relatively low for this type of gear. Coefficients of variation for alewife and smelt, both of which entangled in the gear, were similar. Of these four species, the coefficient of variation was highest for lake whitefish and higher than expected, given that the nets and stations were originally chosen to assess changes in this population and that lake whitefish catches are currently at record-high levels. From these two years of data, there is some indication that sampling variability was lowest for alewife at station 2 during the month of May, for lake trout at station 5 during the month of July, and for lake whitefish at station 3 in August. Sampling variability was lowest for lake whitefish in August but not at any particular station. When the coefficients of variation were averaged for these four species and two years, they were lowest at station 2 and highest at station 4. However, there was no significant difference among the catches at these stations. They were lowest in August and highest in June, but were also not significantly different among the four months sampled. However, the variability associated with catches that were low during the mid-1960s to late 1970s (Casselman et al. 1991) may prove to be unmanageably high.

Sampling variability and the geometric mean catch of these multimesh 50-ft subsamples taken from the subunits produced highly significant negative log-log relationships (Table 2). These strong correlations were encouraging and reinforced the original observation made during a preliminary analysis of the 1989 data that the sampling variability could be predicted from the size of the catch (Casselman 1990). Predictive regressions of sampling variability and catch were also calculated for these four species (Table 3). These regressions used the log of the coefficient of variation projected for the entire gill net and calculated from the subsamples (divided by the square root of 6) regressed on log arithmetic mean catch for the entire gill net. The correlations were very highly significant but lower for alewife (r = 0.47), lake trout (r = 0.59), and rainbow smelt (r = 0.83) when the 1989 and 1990 data were combined than when the 1989 data were used alone (alewife--r = 0.73; lake trout--r = 0.74; rainbow smelt--r = 0.92) (Casselman 1990) but were not different for lake whitefish (r = 0.59 compared with 0.58).

When the 1989 and 1990 results were combined, the range in the size of the catch was large enough to encompass most of the catch levels observed over the past 30 years, hence these samples and statistics are adequate for estimating most of the range of variability observed in this long-term data set.

This replicate and subsampling design made it possible to calculate confidence limits on the catches. Indeed, the variability was very similar in the two years examined. For this reason, the mean catches for 1989 and 1990 were combined to examine general differences and trends (Table 4). The 95% confidence interval was used to calculate the upper and lower 95% confidence limits. These average intervals were as follows: alewife--1.43; lake trout--1.13; lake whitefish--1.44; rainbow smelt--1.57.

The confidence limits by species, station, and month show some significant differences (Table 4). Significantly more alewife were taken at stations 2 and 3 than at station

6. Significantly fewer lake trout were taken at stations 1 and 2 than at any of the other four stations. There were significantly fewer lake whitefish taken at station 3 than at any other station, and significantly fewer smelt were taken at stations 4, 5, and 6 than at stations 1, 2, and 3. There was no difference among months for alewife. There were significantly more lake trout taken in June than in May and significantly more in July than in any other month. There were significantly more lake whitefish taken in August and July than in May and June, and catches were lowest in June. Also, there were significantly more smelt taken in August than in July, and both were significantly higher than May and June catches.

In summary, more lake trout are taken in July than in any other month, and more smelt are taken in August. Lake whitefish catches are probably highest in August, although they are also high in July. In the other extreme, lake whitefish catches appear to be lowest in June.

Replicate Trawling

Replicate trawling was carried out in 1988 and 1990 with four drags per site and three drags per site, respectively. Sampling variability, as indicated by the coefficient of variation, was generally lower for most species in 1990 than in 1988. However, these differences were not significant when the results for the six stations were compared (Table 5). The average coefficient of variation for the five species taken most frequently in the trawls was high (CV = 52.4). For the four species (alewife, lake trout, lake whitefish, rainbow smelt) that were taken most frequently in gill nets, the average coefficient of variation was slightly lower (CV = 49.5%). This compares with an average sampling variability in gill nets of 12.9% (Table 1). Variability in trawl catches of these four species was an average of 3.8 times greater than in the gill-net catches. Approximately 15 times as much trawling effort would be required to obtain the same level of sampling variability. Sampling variability for the trawls was an average of 21.2 times greater than for the gill nets for lake trout, 3.9 times for lake whitefish, 2.0 times for alewife, and virtually identical (1.0 times) for rainbow smelt. Trawls catch smaller, younger fish than do gill nets. Sampling variability for young life stages is higher. It therefore follows that trawls catch smelt of the same age with appreciably lower variability than do gill nets. If further follows that trawling in the Outlet Basin probably samples young smelt much more consistently than do gill nets.

As with the gill-net catches, there were significant but negative log-log correlations between the observational variability and the geometric mean trawl catch when the results for the two years of replicate trawling were combined (Table 6). The correlation was highest for trout-perch ($r = 0.85$), followed by lake trout ($r = 0.81$), sculpin ($r = 0.78$), lake whitefish ($r = 0.76$), and rainbow smelt ($r = 0.68$). The lowest correlation between sampling variability and catch was for alewife ($r = 0.31$), which was significant at the 5% level, while these relationships were highly significantly correlated for the other five species (Table 6). The lower correlation for alewife is not surprising, since no correlation was obtained between sampling variability and catch when only the 1988 replicate trawling data were examined (Casselman 1990). The distribution or behaviour of alewife in the deeper waters of the Outlet Basin appear to be different than that of the other five species most frequently caught in trawls.

Predictive regressions for estimating the geometric mean catch at different levels of sampling variability are now available for the six species most frequently caught when bottom trawling the deep waters of the Outlet Basin in summer (Table 7).

Confidence limits by species for the five species most frequently taken in the trawls (Table 8) indicate considerably more homogeneity when examined by station and month than would be expected or was indicated by the gill nets (Table 4) fished under these conditions. This occurred because the 95% confidence intervals for the trawl catches were extremely broad: highest for sculpin (10.2), followed by lake whitefish (7.9), alewife (6.7), trout (4.9), and lowest for smelt (3.3).

There was no significant difference among the catches at any of the six stations or for any of the four months for the five major species caught in the trawls (Table 8). The only notable values are associated with lake whitefish at station 3. The trawls caught significantly more lake whitefish at station 3 than at station 4; exactly the opposite was true for gill nets. The trawl catches of whitefish at station 3 were mainly composed of young-of-the-year.

Sampling variability of the trawl catches in the deep waters of the Outlet Basin was large. The confidence limits around the trawl catches even of the species that were caught most frequently were so broad that only very gross differences could be shown to be significantly different.

Future Directions

Replicate subsampling of the standard experimental multifilament gill nets routinely set by Research throughout the summer at the six deep-water stations in the Outlet Basin to index the fish community is now complete. A detailed analysis of these data will be conducted. This report provides some cursory preliminary observations. Expanded analyses will be performed to examine the relative significance of changes in the catch that have been observed over the 30 years that data have been collected in this long-term trend-through-time research series. Since sampling variability and the size of the catch are significantly negatively correlated, it may be possible to hindcast sampling variability in this long-term data set by using mean catch data.

However, it is now apparent that replicate subsampling of gill nets will become routine for future research studies involving gill-net sampling. It is also apparent that recommendations can now be made to reduce sampling effort for some species such as lake trout. Analyses from this study will be used to determine whether practical predictive relationships exist that make it feasible to design a monitored sampling program which can be conducted in an interactive fashion so that just enough sampling effort can be applied to attain a specific level of sampling variability.

Replicate trawling has proved that trawl catches are extremely variable. In the past, three to four replicate drags have been used to examine this variability. In 1991, trawling will be conducted at fewer stations, and the number of replicate trawls will be increased to six at each station to determine whether the extreme variability observed is

real or an artifact of the replication design. Replicate trawling in the Bay of Quinte indicates that trawl catches under these conditions may simply be extremely variable.

Analysis of the replicate sampling will be conducted to assess the influence of environmental variables such as temperature. The effects of migratory movements of species throughout the Outlet Basin as reflected by sampling variability will also be examined. Replicates and subsamples will be examined to determine whether time, space, and, in the case of gill nets, orientation in relation to other mesh sizes affect the size and variability of the catch.

A study of sampling variability associated with the new standard monofilament gill nets will commence in 1991.

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TABLE 1. The 1989 and 1990 projected observational variability calculated using geometric mean catch, expressed as the coefficient of variation (CV) separated by station and month for four species caught in the standard white multifilament experimental gillnet ranging in mesh size from 1.5 to 6 inches fished in the Outlet Basin of Lake Ontario 26 to 38 m deep at six stations once during each of May, June, July, and August. The variation for the entire net, which is composed of 2 x 150-ft (45.72 m) intervals of each mesh, was projected by subsampling the catch of the entire standard net by 50-foot (15.24-m) intervals. The projected variations were calculated by dividing the variation of the subsamples by the square root of the effort (square root of 6--2.45). The samples sizes, means, and 95% confidence intervals are provided.

Variable	N	Alewife		Lake trout		Lake whitefish		Rainbow smelt		Mean	95% C.I.
		1989	1990	1989	1990	1989	1990	1989	1990		
Station No.											
1[a]	4	10.3	14.3	5.3	3.3	14.9	18.7	5.3	10.4	10.3	4.5
2[a]	4	6.9	7.4	4.6	4.5	17.1	15.2	5.2	12.0	9.1	4.2
3[b]	4	9.5	10.4	2.7	3.8	23.3	20.7	7.2	6.0	10.5	6.4
4[a]	4	14.6	10.5	2.3	6.0	42.5	7.4	45.9	12.0	17.7	14.1
5[a]	4	10.1	10.5	2.6	2.1	11.3	44.8	20.0	30.0	16.4	12.2
6[c]	4	21.4	12.4	2.4	3.1	22.0	18.6	7.5	15.4	12.9	6.6
Month											
May	6	8.2	8.8	4.6	3.5	36.9	20.4	25.0	16.7	15.5	9.7
June	6	8.9	9.4	2.5	4.9	25.2	40.5	25.7	20.0	17.1	10.9
July	6	13.9	13.2	1.6	2.4	18.1	12.7	5.0	14.3	10.2	5.2
Aug.	6	17.4	12.2	4.6	4.4	7.5	12.2	5.1	6.9	8.8	3.9
Overall mean	24	12.1	10.9	3.3	3.8	21.8	21.5	15.2	14.4	12.9	5.8

[a] Approximately 30 m deep.
[b] < 30m deep (approximately 25 m).
[c] > 30 m deep (approximately 35 m).

TABLE 2. Log-log relations between the observational variability expressed as coefficient of variation (CV) and the geometric mean catch for four species caught in 50-foot (15.24-m) subsamples of the standard white multifilament experimental gillnets ranging in mesh sizes from 1.5 to 6 inches fished in the Outlet Basin of Lake Ontario 26 to 38 m deep at six stations during 1989 and 1990, once during each of May, June, July, and August. The variation was calculated by subsampling the catch of the standard net. Six subsamples, each composed of 50-foot (15.24-m) intervals, were drawn from each mesh size. Catch of the 50-foot interval net is expressed as numbers and CV as percent. Sample size, correlation coefficients, and probabability levels are provided.

Species	Regression equation: dependent variable CV; independent variable geom. mean catch	N	r	P
alewife	LogY = 1.787 - 0.391LogX	48	0.580	0.000
lake trout	LogY = 1.807 - 0.709LogX	48	0.650	0.000
lake whitefish	LogY = 1.699 - 0.372LogX	46	0.613	0.000
rainbow smelt	LogY = 1.764 - 0.508LogX	47	0.847	0.000

TABLE 3. Predictive regressions of the log-log relations between the projected observational variability expressed as coefficient of variation (CV) and the arithmetic mean catch for four species caught in the standard white multifilament experimental gillnet ranging in mesh size from 1.5- to 6-inch fished in the Outlet Basin of Lake Ontario 26 to 38 m deep at six stations in 1989 and 1990, once during each of May, June, July, and August. The variation was projected by subsampling the catch of the standard net by 50-foot (15.24-m) intervals. The projected variation was calculated by dividing the coefficient of variation of the subsamples by the square root of the effort (square root of 6--2.45). Catch of the entire net, composed of 2 x 150-foot (45.72-m) intervals of each mesh, is expressed as number and the coefficient of variation as percent. Sample sizes, coefficients of variation, and probability levels are provided.

Species	Regression equation: dependent variable CV; independent variable arith. mean catch	N	r	P
alewife	LogY = 1.612 - 0.327LogX	48	0.468	0.000
lake trout	LogY = 1.860 - 0.652LogX	48	0.591	0.000
lake whitefish	LogY = 1.640 - 0.381LogX	46	0.590	0.000
rainbow smelt	LogY = 1.813 - 0.520LogX	47	0.834	0.000

TABLE 4. The combined 1989 and 1990 geometric mean catch (CUE) and 95% confidence limits (lower--LCL, upper--UCL) separated by station and month for four species caught in the standard white multifilament experimental gillnet ranging in mesh size from 1.5 to 6 inches fished in the Outlet Basin of Lake Ontario 26 to 38 m deep at six stations once during each of May, June, July, and August. The confidence limits were calculated from projected variance obtained by subsampling the catch of the standard net by 50-foot (15.24-m) intervals. The projected variance was calculated by dividing the variance of the subsamples by the square root of the effort (square root of 6--2.45). Catch of the entire net, composed of 2 x 150-foot (45.72-m) intervals of each mesh, is expressed as number per 100 m^2 of net. Sample sizes are provided.

Variable	N	Alewife			Lake trout			Lake whitefish			Rainbow smelt		
		CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL
Station No.													
1[a]	8	5.2	3.5	7.6	5.4	4.6	6.1	0.9	0.7	1.2	8.2	6.1	10.9
2[a]	8	7.9	6.1	10.1	4.2	3.6	4.8	1.2	0.9	1.6	7.3	5.4	9.9
3[b]	8	5.9	4.3	8.2	7.3	6.5	8.2	0.3	0.3	0.4	5.8	4.7	7.2
4[a]	8	4.2	2.9	6.0	7.8	6.7	9.1	1.6	0.9	2.8	1.7	0.9	3.5
5[a]	8	4.8	3.5	6.6	7.9	7.2	8.6	0.8	0.5	1.2	1.6	1.0	2.7
6[c]	8	2.5	1.6	3.7	7.0	6.3	7.7	2.8	1.0	2.1	3.3	2.5	4.5
Month													
May	12	4.7	3.7	6.2	5.1	4.0	5.2	0.6	0.4	0.9	1.1	0.8	1.6
June	12	5.4	4.0	7.3	3.7	5.5	7.1	0.3	0.2	0.4	1.2	0.8	1.9
July	12	5.7	3.6	8.8	9.7	9.0	10.4	1.2	0.9	1.6	5.1	3.8	6.9
Aug.	12	4.4	2.8	6.9	5.7	5.0	6.8	1.9	1.5	2.4	11.2	8.8	14.1
Overall mean	48	5.1	3.5	7.3	6.6	5.8	7.4	1.1	0.7	1.5	4.7	3.0	7.4

[a] Approximately 30 m deep.
[b] < 30m deep (approximately 25 m).
[c] > 30 m deep (approximately 35 m).

TABLE 5. The 1988 and 1990 observational variability calculated using geometric mean catch expressed as coefficient of variation (CV) separated by station and month for five species caught in the Outlet Basin of Lake Ontario in a 1/2-mile (804.7-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at a depth of 26-38 m. Four replicate drags were made in 1988 and three in 1990 once during each of May, June, July, and August, at six stations. The sample sizes, means, and 95% confidence intervals are provided.

Variable	N	Alewife		Lake trout		Lake whitefish		Rainbow smelt		Slimy sculpin		Mean	95% C.I.
		1988	1990	1988	1990	1988	1990	1988	1990	1988	1990		
Station No													
1[a]	4	8.8	5.8	31.2	18.7	39.3	71.8	3.6	5.8	19.7	36.8	24.2	15.3
2[a]	4	24.2	7.0	157.8	32.8	65.2	132.7	18.4	7.5	34.9	73.1	55.3	37.6
3[b]	4	37.7	11.4	200.0	37.2	67.6	38.1	41.4	4.8	67.2	58.0	56.3	39.1
4[a]	4	28.5	37.2	91.8	61.9	149.2	89.8	14.7	9.2	94.3	07.2	68.4	32.6
5[a]	4	40.9	21.3	63.9	42.4	103.4	84.9	15.5	10.8	31.0	89.6	50.4	23.7
6[c]	4	30.9	8.6	110.9	73.4	80.0	173.3	7.9	3.8	59.1	120.2	66.8	40.3
Month													
May	6	92.2	16.5	200.0	68.6	71.3	91.3	83.0	10.4	118.4	79.4	83.1	37.8
June	6	22.2	11.8	124.4	52.3	94.9	95.6	21.9	6.3	30.4	70.4	53.0	29.5
July	6	20.4	9.4	139.1	40.3	104.7	84.6	6.4	4.8	37.2	73.4	52.0	33.2
Aug.	6	33.8	23.2	49.2	20.5	57.3	78.0	15.6	6.4	76.9	97.1	45.8	22.0
Overall mean	24	29.0	15.2	108.3	44.4	82.4	87.5	18.2	7.0	51.9	80.4	52.4	25.3

[a] Approximately 30 m deep.
[b] < 30 m deep (approximately 25 m).
[c] > 30 m deep (approximately 35 m).

TABLE 6. Log-log relations between the observational variability expressed as coefficient of variation (CV) and the geometric mean catch for five species caught in 1988 and 1990 in the Outlet Basin of Lake Ontario in a 1/2-mile (804.7-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at a depth of 26-38 m. Four replicate drags were made in 1988, once during each of May, June, July, and August at six stations. Catch is expressed as number and CV as percent. Sample size, correlation coefficients, and probability levels are provided.

Species	Regression equation: dependent variable CV; independent variable geom. mean catch	N	r	P
alewife	LogY = 1.438 - 0.138LogX	39	0.305	0.032
lake trout	LogY = 1.886 - 0.584LogX	38	0.807	0.000
lake whitefish	LogY = 1.954 - 0.446LogX	35	0.764	0.000
rainbow smelt	LogY = 2.629 - 0.570LogX	43	0.675	0.000
slimy sculpin	LogY = 2.056 - 0.437LogX	39	0.781	0.000
troutperch	LogY = 1.884 - 0.437LogX	21	0.851	0.000

TABLE 7. Predictive regressions of the log-log relations between the observational variability expressed as coefficient of variation (CV) and the geometric mean catch for five species caught in 1988 and 1990 in the Outlet Basin of Lake Ontario in a 1/2-mile (804.7-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at a depth of 26-38 m. Four replicate drags were made in 1988, once during each of May, June, July, and August at six stations. Catch is expressed as number and CV as percent. Sample size, correlation coefficients, and probability levels are also provided in Table 6.

Species	Regression equation: dependent variable geom. mean catch / independent variable CV
alewife	LogY = 3.108 - 0.671LogX
lake trout	LogY = 2.240 - 1.116LogX
lake whitefish	LogY = 2.677 - 1.308LogX
rainbow smelt	LogY = 3.799 - 0.800LogX
slimy sculpin	LogY = 3.197 - 0.401LogX
trout-perch	LogY = 3.296 - 1.653LogX

TABLE 8. Combined 1988 and 1990 geometric mean catch (CUE) and 95% confidence limits (lower--LCL, upper--UCL) separated by station and month for five species caught in the Outlet Basin of Lake Ontario in a 1/2-mile (804.7-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at a depth of 26 to 38 m. Four replicate drags were made in 1988 and three in 1990, once during each of May, June, July, and August, at six stations.

Variable	N	Alewife			Lake trout			Lake whitefish			Rainbow smelt			Slimy sculpin		
		CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL
Station No.																
1[a]	8	1579	800	3115	7.0	3.8	13.0	3.3	1.1	9.9	3055	1833	5092	20.2	6.3	65.1
2[a]	8	1079	292	3986	5.6	0.7	46.2	1.7	0.4	6.5	1027	342	3083	21.6	2.2	214.8
3[b]	8	580	76	4399	4.7	0.6	37.1	17.0	2.3	123.5	2012	8	5026	9.4	1.3	66.0
4[a]	8	567	36	8963	3.3	0.8	13.6	0.8	0.3	2.1	1404	475	4147	3.9	0.5	30.4
5[b]	8	243	29	2027	4.4	1.4	14.1	2.4	0.6	10.2	1977	559	6986	17.7	1.5	206.0
6[c]	8	1644	285	9472	3.9	0.7	23.0	0.9	0.3	2.6	2230	18	2815	5.9	0.6	62.4
Month																
May	12	1568	115	21323	3.5	0.6	20.5	3.4	0.6	18.3	2421	298	19688	5.9	0.7	49.6
June	12	709	166	3023	4.0	0.7	23.7	2.9	0.5	15.6	1299	349	4831	26.4	3.2	214.5
July	12	1060	275	4084	3.4	0.7	15.8	3.4	0.6	20.6	2497	1399	4457	12.3	2.2	69.9
Aug.	12	492	50	4888	7.6	3.0	19.4	11.0	1.3	91.4	2318	766	7016	13.2	0.7	255.9
Overall mean	48	942	142	6279	4.8	1.0	23.5	5.5	0.7	43.7	2100	643	6854	13.7	1.3	139.7

[a] Approximately 30 m deep.
[b] < 30m deep (approximately 25 m).
[c] > 30 m deep (approximately 35 m).

Research Project: Lake Trout Rehabilitation Studies

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Routine sampling of the spawning population that frequented Yorkshire Bar in late October, 1990, indicated that slightly more lake trout were present than in the previous year and that there were four to five times as many as in 1987 and 1988, when mark-recapture was used to estimate the spawning population at 1,000 mature lake trout. More females were present than in previous years. Most of these fish were mature for the first time. Lake trout in 1990 more actively frequented and deposited eggs on the peak of the bar than in former years, when they used the steep east slope. Likewise, in 1990, the greatest numbers of lake trout were observed in shallower water 1 to 2 m deep over the clean, wave-washed, inshore rubble. Peak spawning probably occurred early in the last week of October. Egg surveys conducted by divers indicated that the greatest densities of eggs were at 1 and 3 m, that over the spawning period there was an average of 54 eggs per m^2, and that at least 50% of these were dead. The fertilization rate was directly related to size (age) of the lake trout, and for small females (approximately 600 mm FL), it ranged from 0% to 15%. *In situ* incubation of Lake Manitou eggs as controls and of Lake Ontario eggs produced some significant results which indicated that there was no significant difference in the number of fry that hatched either by source or by location of the incubator but that there were considerably more live fry produced from Lake Ontario eggs than from Lake Manitou eggs. The only difference between these two treatments was that the Lake Manitou eggs were installed some 16 days earlier and in water that was 3.6 degrees C warmer. Appreciably more cells of the incubators containing Lake Manitou eggs were empty, an observation that could be explained by the fact that decomposition was advanced in this treatment. Likewise, a reduced rate of development for the Lake Ontario source meant that appreciably more dead eggs were present in the Ontario incubators when they were removed. There is some evidence to support the hypothesis, which is currently being tested, that early egg deposition by some hatchery stocks results in eggs being deposited at relatively high temperatures in heavily silted rubble, which has not been adequately purged by fall winds, and that by virtue of temperature has a high biological oxygen demand and that these conditions detrimentally affect survival and development of the eggs. It follows that in degraded eutrophied environments, deposition of eggs later in the fall at lower water temperatures would be advantageous. A significant mortality (approximately 30%) occurs at time of swim-up in eastern Lake Ontario fry. Fry hatched from the Lake Ontario lake trout eggs showed significantly more abnormalities (approximately 3%) than those from Lake Manitou eggs. A study of potential deep-water nursery habitats is being conducted, and indigenous lake trout are being discriminated from unmarked hatchery fish by characteristics involving the fins, scales, and otoliths. Of the otoliths of marked hatchery lake trout in Lake Ontario, 70% to 84% have anomalous characteristics associated with a nucleus and optical density and crystallization. The relative size of these important diagnostic characteristics typical of hatchery lake trout have been quantified. A system has been developed for determining the percent chance that an unmarked lake trout is of hatchery origin. Tests of samples of fish of known origin confirm that if the chance is 20% or less, the fish is indigenous. Of the 49 unmarked lake trout that were caught and examined in 1990, 3 proved to be indigenous. It is now apparent that small numbers of indigenous lake trout are present in Lake Ontario and that some have reached the young subadult stage. Four (57%) of the 7 indigenous lake trout caught in the past two years came from two year classes produced during the 1984 and 1987 spawning seasons. It is not surprising that the first multi-occurrence of a year class of indigenous lake trout was associated with the 1984 year class, because in 1984, there was the first large, significant increase (four times the previous year) in the size of the spawning population that congregated on traditional spawning grounds such as Yorkshire Bar.

Background

For the past 16 years, almost 4 million lake trout have been stocked in the Canadian waters of the Outlet Basin of Lake Ontario in an effort to rehabilitate lake trout stocks, which disappeared in the mid-1940s. During the past decade, numbers of mature lake trout have begun to congregate on the spawning shoals. However, substantial numbers of mature fish did not appear on traditional spawning areas such as Yorkshire Bar until approximately 1984 (Casselman 1990). It is now apparent that these congregations of mature lake trout in the fall result in the deposition of fertilized eggs and that some fry are produced. It has been documented at a spawning site off Stony Island in the east end of Lake Ontario that substantial numbers of fry hatch and emerge from the eggs that are deposited (Schneider et al. 1990). Deployment of 100 fry traps each spring for the past 3 years on Yorkshire Bar has, however, produced only one emergent lake trout fry. In 1990, the first indigenous juvenile lake trout were discovered (Casselman 1990). The two lake trout were yearlings and were caught in the research program that samples and studies the deep-water community dynamics of the Outlet Basin of Lake Ontario. More indigenous juvenile lake trout may be present, but it may be that their deep-water habitat is inadequately sampled. It is equally possible that egg amd fry survival and development may not be sufficient to result in detectable numbers of older indigenous juveniles. For this reason, two studies were initiated in 1987: one is associated with spawning and survival and development of early life stages; the other involves juvenile abundance, survival, and nursery habitat. The former deals more specifically with the behaviour and reproductive potential of mature adults at spawning time, spawning and the deposition of eggs, and survival and development of eggs and fry. The other examines the abundance of juveniles, emphasizing the search for indigenous individuals, and examines the deep-water nursery habitat requirements of the juveniles and their associated species interaction.

Lake Trout Spawning and in situ Egg Incubation--1989 and 1990 Studies Update

Background and Objectives

Each fall since 1987, a study has been conducted of the mature lake trout that congregate at spawning time on Yorkshire Bar in the middle of the east end of Lake Ontario. This spawning study has several facets. Data are being accumulated on: (1) The biology and density of the congregations of lake trout that have appeared on the bar. This congregation has been sampled by Research since 1975. (2) The deposition and survival of eggs in relation to environmental conditions and substrate. (3) The survival, development, and hatch of eggs. These include *in situ* and controlled incubation studies, the latter conducted under natural conditions.

The present report provides information concerning (1) changes in the relative density of mature lake trout congregating on Yorkshire Bar at spawning time in 1990; (2) results of egg surveys conducted during 1990; (3) results of a paired *in situ* and controlled incubation study of fertilized Lake Manitou and Lake Ontario eggs that was initiated in the fall of 1989 and completed in spring and early summer of 1990--part of this study was conducted jointly with researchers working on other Great Lakes and the U.S. Fish and Wildlife Service at Ann Arbor, Michigan; (4) preliminary and partial results for another paired *in situ* and controlled incubation study involving fertilized Lake Manitou and Lake Ontario eggs that was initiated in the fall of 1990 and is currently underway.

Diving and gill netting were conducted on six separate occasions on Yorkshire Bar in the fall of 1990. Gill netting was conducted on October 24, 25, and 26. Gill netting and diving observations, which commenced October 12, confirmed that peak spawning activity probably occurred during the last week in October. This is approximately the same time as in 1989 but is earlier than in 1987 and 1988. However, larger numbers of young females mature for the first time were taken in 1990 than in other years. From observations made in 1989, these younger females mature and appear spent earlier than do the older, larger females, which do not appear to be ripe and running freely until approximately the first week in November. In 1990, divers observed small congregations of mature fish circling the peak of the bar as early as October 12. They also noted that fewer lake trout were present on the bar on November 11 than during the last week in October. Early spawning activities in recent years may be because the age and stock origin of the spawning population frequenting the bar has changed over the years. A detailed analysis of the stock origin of the spawning population of Yorkshire Bar is being conducted. However, it is apparent that in recent years, a higher percentage of Lake Manitou fish has been present.

For the first time in this study, substantial numbers of mature females were present. A high percentage of these lake trout were marked with the right pectoral fin clipped. This clip was observed frequently for the first time in 1989, when numbers of males that were mature for the first time appeared at spawning time on Yorkshire Bar.

Experimental index gill netting on the night of October 26, 1990, at a water temperature of 10.2 C with a multimesh gill net ranging in mesh size from 1/2 inch to 6 inches, set for 1 hour, 35 minutes, produced a catch per unit effort that was slightly higher than in 1989. During the past two years, the number of lake trout caught on Yorkshire Bar has increased substantially. This catch and that of 1989 were approximately four to five times higher than the catches of 1987 and 1988 (Table 1). Mark-recapture, which was conducted in 1987 and 1988, indicated that approximately 1,000 mature lake trout frequented Yorkshire Bar at peak spawning time. This number, as indicated by the relative catch statistics, was approximately four to five times that in 1990. In 1989, this increase was primarily because of smaller males, resulting in a decrease in the average weight of the individuals in relation to the former two years of the study (Table 1). The average weight of the fish increased in 1990 as this group of fish aged and became heavier. Also, females of this cohort, which mature later than the males, contributed to the increase observed in 1990. No tagged fish were recaptured at spawning time. Indeed, several tags of fish tagged at Yorkshire Bar at spawning time have been returned by anglers fishing in mid-summer in the general vicinity (within 10 km) of Yorkshire and Main Duck islands.

TABLE 1. Lake trout catch statistics for 14 years (between 1975 and 1990) for gill nets set at spawning time on Yorkshire Bar of Yorkshire Island and for standard Lake Ontario experimental multifilament gill nets set 26 to 38 m deep at six stations throughout the Outlet Basin in the east end of Lake Ontario. Catches are expressed as number and weight of lake trout taken in 100 m^2 of net in 24 hours. The catches in the 2.5- and 3.0-inch mesh panels of multifilament are expressed in the same units. The 1987 to 1990 (except 2.5- and 3.0-inch mesh) netting was conducted with a slightly different type of experimental green monofilament gill net.

	Yorkshire Bar spawning period						June-August		
	2.5-inch and 3.0-inch mesh			1.5 to 6.0-inch mesh experimental gill net			1.5 to 6.0-inch mesh experimental gill net		
	CUE		Average	CUE		Average	CUE		Average
Year	N	kg	wt (kg)	N	kg	wt (kg)	N	kg	wt (kg)
1975	0.00	0.00		0.40	0.06	1.508	0.22	0.71	0.966
1976	0.00	0.00		0.00	0.00		0.22	0.24	1.106
1977	0.28	0.47	1.68	0.47	0.78	1.646	0.41	0.35	0.857
1978	0.75	1.02	1.36	0.54	0.70	1.294	0.76	0.71	0.932
1979	0.30	0.47	1.55	0.36	0.73	2.048	0.96	1.32	1.402
1980	0.30	0.49	1.64	0.60	1.34	2.248	2.74	2.86	1.044
1981	1.39	2.42	1.74	1.21	2.95	2.426	1.77	2.27	1.279
1982	1.80	3.04	1.69	1.79	3.57	1.994	2.59	2.99	1.154
1983	4.19	9.60	2.29	4.96	12.30	2.481	4.19	6.04	1.442[a]
1984	16.73	42.40	2.54	19.84	52.11	2.626	5.38	10.38	1.929[a]
1985							6.73	13.88	2.062
1986							5.26	10.42	1.980
1987	[78.23	216.38	2.766[c]	[60.55	176.32	2.912[c]	10.49	21.59	2.059
1988	[137.20	389.00	2.835[c]	46.22	131.68	2.849[d]	6.32	13.62	2.156
1989	323.16	950.08	2.940[d]	253.44	595.33	2.349[d]	8.80	20.37	2.317
1990	229.73	648.07	2.821[b]	268.70	742.15	2.762[d]	7.53	17.31	2.299

[a]Estimated catch.
[b]Catch data for 2.5- and 3.0-inch mesh combined and adjusted for activity on spawning grounds to approximate the CUE for a 24-hour period to make the results generally comparable to other years.
[c]Estimated catch calculated from previous catch relationship between 2.5- and 3.0-inch mesh and 1.5- to 6.0-inch mesh experimental gill-net sets on Yorkshire Bar, since only 2.5- and 3.0-inch mesh gill nets were used in 1987.
[d]Catch data for 1.5- to 5-inch mesh, green monofilament, experimental gill nets set for 1 to 6 hours, and adjusted for activity on the spawning grounds to approximate the CUE for a 12-hour period to make the results generally comparable to other years.

The general distribution and movement of lake trout observed on the bar in the fall of 1990 were generally similar to those reported in recent years (Casselman 1990). However, it appeared that in 1990, lake trout more actively frequented the peak of the bar than the steeper east slope. When the divers were installing incubators on October 24, 25, 31, and November 11, they reported that lake trout were observed in much shallower water than in previous years. In previous years, this schooling-up effect was noticed from 3 to 6 m. However, during 1990, large numbers of fish were observed in water shallower than 3 m. Divers reported that this rubble inshore was much cleaner but very shallow, probably only two particles deep. It appeared that the lake trout were actively seeking the clean, inshore rubble in 1990. In fact, the greatest congregations of lake trout were observed in 1 and 2 m of water when the experimental index gill net was set on October 26.

Egg traps were not employed in 1990 because the traps that had been designed and used on the bar in previous years were not quantitative (Casselman 1990). Divers conducted a systematic survey on the peak of the bar, using a randomly tossed 50-by-50-cm square metal frame for locating the survey location. The rubble in the defined area was then carefully mined away. The procedure was videotaped, and the numbers of live and dead eggs were enumerated. Egg shells were observed during this process; however, they were not as prevalent as in 1989. No eggs or cleaned substrate were observed on October 12 (Table 2), although there was a small congregation of lake trout circling on the peak of the bar at that time. Eggs were observed on the four subsequent surveys--October 24, 25, 31, and November 11. Early in the season, egg deposition was highest in shallower water. Overall, egg densities were greatest in shallow water, 1 m, and approximately 3 m. Over this period, an average of 84 eggs were estimated per m^2 at 1 m depth, 40 at 2 m, 96 at 3 m, 51 at 4 m, and 21 at 5 m. Overall deposition independent of depth over this depth range was 54 eggs per m^2. Egg densities in 1990 appeared to be slightly lower than in 1989, when it was estimated that there were approximately 100 eggs per m^2. However, the 1989 observations were made later in the season, on November 27.

TABLE 2. Lake trout egg survey conducted by divers on Yorkshire Bar, 1990. Numbers were counted by carefully mining out the substrate from a known area of bottom. A thin square metal frame 50 x 50 cm was randomly thrown from the surface at various depths along the peak of the bar. These numbers were used to estimate the number of eggs per square metre of bottom. Dead eggs were opaque and light in colour.

Date	Temp. (C)	Oxygen (mg/l)	Depth (m)	Eggs				
				Dead		Alive		Total N
				N	%	N	%	
Oct. 12	14.9							
Oct. 24[a]	12.8	10.0	3	12	17	60	83	0
			4	0	0	20	100	72
			5	8	33	16	67	20
			Mean	7	17	32	83	24
Oct. 25[b]	12.1	9.9	3	48	67	72	33	39
			4	12	25	16	75	120
			5[c]	0		0		28
			Mean	20	46	20	54	0
Oct. 31	10.5	10.5	3	16	17	80	83	49
			4	48	67	24	33	96
			5	20	33	40	67	72
			Mean	28	39	48	61	60
Nov. 11	9.7	10.6	1	48	57	36	43	76
			2	28	70	12	30	84
			3	20	36	36	64	40
			4	24	29	60	71	56
			5	0		0		84
			Mean	24	48	29	52	0
								53

[a] Survey conducted after incubators with Lake Manitou lake trout eggs installed.
[b] Survey conducted after incubators with Lake Ontario lake trout eggs installed.
[c] 5-m depth not surveyed on peak of Yorkshire Bar but along steeper east slope.

It is apparent that egg deposition in 1990 was somewhat earlier, because in 1989 no eggs were observed on October 23, whereas on October 24, 1990, an average of 39 eggs per m^2 were observed across depths ranging from 3 to 5 m. This is supported by the observation that smaller, younger females, which ripen earlier, were more common on the bar in 1990 than in 1989.

Of the eggs that were observed during the survey, it was easy to separate those which appeared alive from those which were definitely dead: dead eggs were white and opaque. It is possible that some of the eggs classified as alive had only recently been deposited and were not properly fertilized. Therefore, this estimate might overestimate actual conditions. On October 24, 83% of the eggs that were observed were considered to be alive (Table 2). The percentage of live eggs was lower in subsequent surveys: 54% on October 25, 61% on October 31, 52% on November 11. Therefore, of the eggs deposited on Yorkshire Bar, at least 50% died. This was lower than seen in 1989, when it was estimated on November 27 that only one-third of the eggs were dead (Casselman 1990). The viability of the eggs deposited by these younger females is in some question, since eggs of the three smallest of the seven lake trout stripped of eggs on October 25 had essentially a zero fertilization rate. Although their eggs appeared normal, none of the eggs of two of the trout were successfully fertilized, and for another, only 3% of the eggs proved to be fertilized successfully. Of the four females that provided eggs in 1989, the smallest fish had the lowest fertilization rate--only 15%.

Data on the genetic origin of the spawning population have been collected, but results are not available at the present time. However, preliminary electrophoretic data provided by Dr. Peter Grewe of Cornell University for eggs that were naturally deposited and collected on Yorkshire Bar on November 27, 1989, indicated the following genetic proportions: Killala 37%, Manitou 27%, Superior 25%, Seneca 11%, Clearwater 1%.

Since 1988, eggs have been collected at spawning time from the spawning population on Yorkshire Bar to examine egg fertilization, survival, and hatch.

Each year since 1988, *in situ* incubation has been conducted with these eggs. In 1988, the incubators were not installed on Yorkshire Bar but were installed by John Fitzsimons of Fisheries and Oceans Canada on a spawning shoal in the west end of Lake Ontario, near Grimsby. In 1989 and 1990, incubators were installed at the same location at the 4- to 5-m depth in the rubble on Yorkshire Bar

TABLE 3. Percent occurrence by life stage and condition for incubators (50 cells each) loaded with fertilized eggs of Lake Manitou lake trout on October 22, 1989, and Lake Ontario lake trout eggs on November 7 and installed the next day (at water temperatures of 11.2 and 8.6 C respectively) on the steep east slope of Yorkshire Bar opposite peak at the 4- to 5-m depth. The Lake Ontario eggs were installed on Yorkshire Bay 16 days after the Lake Manitou eggs. The incubators were removed April 13 and 19 and contents of each cell were examined. The inshore end of the shallow chain, with a floatline attached, was drug across the middle of the outer chain on approximately March 22, when heavy pack ice that had accumulated on the bar drifted away in gale-force winds and caused substantial ice scouring and disruption of some incubators. Detailed examination of the location of each incubator when it was removed from the bar documented that some incubators remained undisturbed in the rubble, while others were pulled out and were on the surface of the bar when removed. The number of incubators (N) and means and 95% confidence intervals, expressed as percent of total number of egg cells, are provided.

		Empty cells		Dead eggs[a]		Fry							
						Dead, decomposed[b]		Recently dead		Alive		Total	
Source	N	$\bar{x}$	C.I.	$\bar{x}$	C.I.	$\bar{x}$	C.I.	$\bar{x}$	C.I.	$\bar{x}$	C.I.	$\bar{x}$	C.I.
Ontario	42	10.2	3.5	45.2	4.3	16.8	3.5	0.9	0.8	25.6	5.6	3.3	4.5
In rubble	11	6.7	3.9	45.8	8.6	8.2	2.7	0.0	0.0	39.3	9.3	7.5	10.1
Exposed	24	12.6	5.7	43.8	6.1	20.2	4.9	1.1	0.9	20.7	7.2	1.9	6.4
Manitou	43	22.7	3.5	37.4	3.3	26.6	3.8	0.5	0.4	13.3	4.6	0.3	4.9
In rubble	13	16.8	6.2	31.7	7.7	21.7	8.0	0.2	0.3	29.2	5.2	1.1	11.1
Exposed	28	25.5	4.5	38.3	3.8	28.6	4.6	0.6	0.6	6.6	3.3	5.9	5.0
Combined	85	16.6	2.8	40.7	2.8	21.7	2.7	0.7	0.4	19.4	3.8	1.8	3.3

[a]Microscopic examination indicated that eggs shells and contents were intact.
[b]Microscopic examination indicated that parts of fry were present and that the egg shell was missing or, if present, was not intact.

(Casselman 1990). In conjunction with this work, eggs and sometimes incubators loaded as controls were transported to Dr. Bruce Manny of the U.S. Fish and Wildlife Service, at Ann Arbor, Michigan, and to other researchers working on other Great Lakes spawning populations. The results of these comparative studies will be presented in detail elsewhere.

The *in situ* incubation study initiated in the fall of 1989 was completed in 1990. Equal numbers of incubators containing Lake Manitou and Lake Ontario eggs were installed on Yorkshire Bar on October 23 and November 8, 1989, respectively. During the intervening time, which was 16 days, water temperature dropped from 11.2 C to 8.6 C. Installation of the two egg lots was identical except for the difference in time of installation and the duration of exposure. On approximately March 26, a heavy offshore wind removed the pack ice over the incubators, causing the end of one chain of incubators to be drug through the middle of the other. The incubators containing the two types of eggs were attached alternately along the chain. This meant that 11 incubators containing Lake Ontario eggs and 13 incubators containing Lake Manitou eggs were left intact in the rubble, and 24 incubators of Lake Ontario eggs and 28 incubators of Manitou eggs were ripped out of the rubble and remained exposed on the bottom until all the incubators were removed on April 13 and 19. Sediment traps have always been installed on the bar along with the incubators, and their contents are being analyzed.

However, during fall, winter, and spring of 1989/90, Yorkshire Bar was heavily silted; this sediment was greater than during 1988/89. The heavy winter siltation may be because heavy ice formation in the eastern basin produced a prolonged ice cover over the bar and adjacent waters, possibly preventing wind-driven currents from purging the fall silt load from the bar.

When the incubators were removed in mid-April, some live yolk-sac fry were present, along with various stages of dead and decomposing, yet readily recognizable, eggs and fry. When the incubators were removed, the live fry were absorbing their yolk sac and had developed to a stage where they were 20 to 40 days prior to 'swim-up'. When the incubators were removed, there was no significant difference between the number of fry that had hatched when the two sources, Ontario and Manitou, were compared (mean = 43.1%) and between whether the incubator was in the rubble or exposed when it was removed (Table 3). The similarity in hatch rate was of special interest, because there were significantly more live fry (2 times) from the Lake Ontario source (25.6%) than from the Manitou source (13.3%). Also, there were significantly more live fry in the incubators that remained in the rubble than in the ones that were exposed. For the Ontario source, this was approximately 1.3 times as many (39.3% and 29.2%); for the Manitou source, it was approximately 3 times as many (20.7% and 6.6%). When the incubators were opened, a small number of fry were found that had recently died but the number was not significantly different either for source or final location of the incubator. However, the Manitou incubators contained significantly more fry (26.6%) that had been dead for some time and were heavi-

TABLE 4. General results of the development and survival of lake trout eggs and fry from a joint study conducted by researchers working on Lake Michigan and on western and eastern Lake Ontario during 1989 and 1990. Eggs from Lake Manitou were used as controls. Results apply to loose egg controls; data were collected and summarized by B. Manny, U.S. Fish and Wildlife Service, Ann Arbor. Eggs were subsamples of the Lake Manitou lot that were were placed in incubators and installed on Yorkshire Bar on October 23, 1990, at 11.2 C and of the eastern Lake Ontario lot that were similarly loaded in incubators and installed on November 8, 1990, at 8.6 C. Results of these *in situ* incubation studies are provided in Table 3.

	Source			
			Ontario	
Parameter	Manitou	Michigan	Western	Eastern
No. mature fish used				
females	>20	>30	7	4
males	>20	>50	12	6
Fertilization date	Oct. 22	Oct. 24	Oct. 30	Nov. 7
Fertilization (%)	98	98	86	99
Hatch (%)	88	89	52	59
% die-off at swim-up[a]	0	10	23	30

[a]Approximate averages for several lots.

ly decomposed than did the Ontario incubators (16.8%). Also, the incubators that contained Ontario eggs and were exposed had significantly more heavily decomposed fry (2.5) that had been dead for some time than did those that were still intact in the rubble.

Incubators with Ontario eggs had significantly more dead eggs than did those with Manitou eggs, regardless of location. Although incubators were loaded carefully and a preliminary examination at time of installation indicated that few if any cells had been missed and were empty, nevertheless, when the incubators were removed, there were more than twice as many (2.2 times) empty cells in the incubators with Manitou eggs as in those with Ontario eggs.

The 1989/90 results may appear complicated; however, there are some important and salient points which indicate that development was advanced in the Manitou eggs and that this advanced development was associated with increased mortality. The basic difference in treatment between the two egg sources was that the Lake Manitou eggs were installed on the bar much earlier and at a higher water temperature. In all other ways, the treatments were identical. There was no significant difference in the numbers of fry, either by source or by location of the incubator, when the incubators were removed. But generally, there were considerably more live fry in the Lake Ontario source and considerably more fry that had been dead for some time in the Manitou source. Appreciably more of the cells of the incubators containing eggs of Manitou source were empty, possibly explained by the fact that decomposition had advanced to the point where no discernible contents remained. Likewise, a reduced rate of development for the Lake Ontario source meant that appreciably more dead eggs remained in the Ontario incubators when they were removed and examined.

In situ incubation indicated that more than one-half of the fertilized eggs installed on Yorkshire Bar, regardless of whether they originated from Lake Manitou or Lake Ontario trout, did not survive to hatch, even though fertilization rates were relatively high (Table 4). Loose egg controls that also compared eggs from lake trout from Lake Michigan and western Lake Ontario indicated that hatch rates were lower for Lake Ontario sources than for the Manitou and Michigan sources. In addition to this mortality, there is a die-off at time of swim-up. Loose egg controls held by B. Manny, U.S. Fish and Wildlife Service at Ann Arbor, indicated that this mortality was higher for eastern Lake Ontario (30%) than for western Lake Ontario (23%) and Lake Michigan (10%) but was nonexistent for fry from the Lake Manitou control. This phenomenon has been referred to as "contaminant syndrome". This mortality was equally high for eggs collected in 1988 from Yorkshire Bar, ranging from 23% to 32% (Casselman 1990). In addition, 2.6% of the fry that hatched from eggs collected in 1988 were deformed. This was significantly higher than from other Great Lakes sources except for the west end of Lake Ontario (Table 4). A detailed analysis and presentation of the *in situ* incubation studies that have been conducted jointly across the Great Lakes will be presented elsewhere (B. Manny, unpublished data).

In the fall of 1990, another *in situ* incubation study was initiated. It involved Lake Manitou eggs as controls and eggs from lake trout collected from the spawning population on Yorkshire Bar. The two lots of eggs were installed on Yorkshire Bar at virtually the same location as in 1989--Lake Manitou source on October 24 at 12.8 C and Lake

TABLE 5. General results for the development and survival of lake trout eggs and fry for loose egg controls reared in Heath tray vertical incubators at the Glenora Fisheries Station in Lake-on-the-Mountain surface water in a comparison between Lake Manitou and Lake Ontario eggs collected in the fall of 1990. Eggs are subsamples of the Lake Manitou lot, which were placed in incubators and installed on Yorkshire Bar on October 24, 1990, at a water temperature of 12.8 C and Lake Ontario on October 25, 1990, at 12.1 C.

Parameter	Manitou		Ontario	
	Sublot 1	Sublot 2	Sublot 1	Sublot 2
No. mature fish used				
females	16		6	
males	162		12	
Fertilization date	Oct. 22		Oct. 25	
Fertilization (%)	83	82	89	90
Hatch (%)	63	61	81	81
Live fry[a]	59	55	74	72

[a]Percentage of fry that were live at a time comparable to the opening of the incubators on February 5 to 15, results of which are reported in Table 6.

Ontario source on October 25 at 12.1 C. As part of the design, loose egg lots and control incubators containing both Manitou and Ontario eggs were held at Glenora at ambient water temperatures in the surface water supply from Lake-on-the-Mountain. To examine the effects of the time of installation and the duration of early exposure, two lots of incubators containing Manitou eggs were exchanged between Yorkshire Bar and Glenora on October 31 and November 11, 7 and 18 days after initial installation. The ambient water temperatures of Yorkshire Bar on these dates were 10.5 and 9.7 C, respectively.

The entire 1990/91 incubation study is not yet complete. The incubators from Yorkshire Bar will be removed in early April 1991, and all fry will be held to swim-up to examine the swim-up mortality syndrome. However, it appears from the loose egg controls that the fertilization rate (which ranged from approximately 70% to 80% (Table 5)) was lower in 1990 than in the previous year (Table 4) and that hatch was lower for the Manitou eggs and higher for the Lake Ontario eggs. Only approximately 55% to 60% of the Lake Manitou fry in the loose egg controls were alive at a time comparable to opening the incubators, as compared with 70% to 75% for Lake Ontario. In 1990, the Lake Manitou eggs had been collected a day earlier and refrigerated prior to fertilization. This may have caused the lower values for this control lot.

The laboratory incubation phase of the 1990 egg samples is complete. Once all the live eggs that were held in the incubators at Glenora had hatched, the incubators were opened and the contents were examined in the same detail as was used in the 1989-90 study. Four treatments have been examined (Table 6). There were no significant differences between the number of fry that hatched for either the two egg sources or those with short-term exposure to Yorkshire Bar (Table 6). There was some indication that slightly more fry from the earlier and shorter installation on Yorkshire Bar died just prior to the opening of the incubators. There were, however, significantly fewer dead eggs from the Ontario source in the incubators than from the Lake Manitou source. This supports the observations made on the loose-egg controls (Table 5). The only noticeable difference at this stage of the experiment was that a higher percentage of the fry that hatched from the Lake Ontario lake trout eggs showed abnormalities (mean = 3.3%). The frequency of occurrence was low but significant. Spinal deformities and asymmetries were the most common, but other anomalies such as missing structures and two-headedness also occurred. The Manitou fry showed some of these anomalies, but the numbers were not significantly different than 0 (Table 5). The fry from each of these treatments have been separated into sublots and placed in containers to examine survival and development up to and including swim-up.

Future Directions

The future direction of this research will in part depend upon the results of the *in situ* incubation study that is underway. The remainder of the data will be collected when the incubators are removed from Yorkshire Bar this April. One specific hypothesis being tested is that early egg deposition by some hatchery stocks results in eggs being deposited at relatively high temperatures in heavily silted rubble which has not been adequately purged by fall winds and that the associated high biological oxygen demand created by this detritus under these conditions detrimentally affects survival and development of the eggs. It follows that in a degraded environment, delayed and late deposition of eggs would be advantageous. The present experiment was designed to examine whether the time of installation, which simulates different deposition times in the fall, would affect survival and hatch. The range of in-

TABLE 6. Percent occurrence by life stage and condition for incubators (50 cells each) loaded with fertilized Lake Manitou lake trout eggs on October 24, 1990, for Lake Manitou, and Lake Ontario lake trout eggs on October 25, 1990. Incubators were installed on these dates in the rubble on Yorkshire Bar at 12.8 and 12.1 C respectively. This table reports results for control incubators that were held at the Glenora Fisheries Station at ambient water temperatures of Lake-on-the-Mountain surface water. It also includes two lots of incubators, both of which contained Lake Manitou eggs, both of which were installed on Yorkshire Bar on October 24, 1990, and one lot removed 7 days afterwards at a water temperature of 10.5 C and another 18 days later at 9.7 C. Both were then transferred to and held at the Glenora Fisheries Station. Incubators were opened at the Glenora Fisheries Station and examined from February 5 to 15. The number of incubators (N) and means and 95% confidence intervals, expressed as percent of total number of egg cells, are provided.

					Fry				
			Dead eggs[a]	Dead eyed eggs	Dead, decomposed	Alive	Total	Abnormal fry	Blue-sac disease
Source	Rearing location	N	$\bar{x}$ C.I.	$\bar{x}$ C.I.	$\bar{x}$ C.I.	$\bar{x}$ C.I.	$\bar{x}$ C.I.	$\bar{x}$ C.I.	$\bar{x}$ C.I.
Ontario	Glenora	19	25.5 3.0	3.8 2.1	2.8 2.2	66.1 4.3	70.0 3.7	3.3 1.3	1.6 0.9
Manitou	Glenora	18	32.1 3.7	4.0 1.5	7.6 6.9	55.2 8.2	63.3 4.3	0.9 0.9	0.4 0.6
Manitou	Yorkshire 7 days then Glenora	9	28.9 3.4	2.4 1.5	1.3 1.7	63.6 10.6	68.7 3.7	0.7 0.7	1.6 1.5
Manitou	Yorkshire 18 days then Glenora	18	30.6 3.3	4.8 1.4	4.2 2.8	55.7 5.7	63.3 3.7	0.1 0.2	0.9 0.6

[a]No noticeable differentiation.

stallation times that could be tested in the 1990 spring season was not large (up to 18 days), and only very basic water quality and substrate parameters were measured. It is anticipated that a broader range of installation exposures and times will be needed, along with more precise measurements of sedimentation, biological oxygen demand, and interstitial oxygen. This will be attempted in 1991-92 and will require visiting the spawning area more frequently and over a longer period of time. To accomplish this, a survey will be conducted inshore to determine whether a more accessible spawning area and study site can be located. Some preliminary sampling on October 26 indicated that large numbers of ripe lake trout, including a higher percentage of running females than is seen on Yorkshire Bar, frequent the shallow inshore water on the north shore of Adolphus Reach at spawning time. Another potential study location is the Salmon Island bar east of Amherst Island.

The results of *in situ* incubation on Yorkshire Bar appear to be quite consistent. However, it is not known how these results for early development and survival compare with a natural, self-sustaining lake trout population. To obtain these data, it would be necessary to study *in situ* incubation in a spawning area that supports a self-sustaining lake trout population. This will require using an inland-lake spawning site.

Nursery Habitat and Indigenous Juvenile Lake Trout--1990 Study Update

Background and Objectives

Young juvenile lake trout are not sampled very effectively by routine methods. In fact, it has only recently been adequately documented that the nursery habitat of juveniles (up to 4 years of age) is very deep (Casselman 1990; Evans et al. 1990). A literature survey of the vertical midsummer distribution of juvenile lake trout in the Great Lakes indicates that these fish are found at a mean depth of 56 m but that their distribution, as indicated by the 95% confidence limits, ranges from 44 m to 68 m. This is well below the adults, which have a midsummer vertical distribution that averages 29 m and ranges from 19 m to 39 m.

The purpose of this study is to sample potential deep-water nursery habitat of juvenile lake trout to determine whether indigenous individuals are present. Fine-mesh green monofilament gill nets with a continuously hung lead line are used in this study because, from inland lake studies, it has been shown that they catch juvenile lake trout with a lower sampling variability than do other types of gill nets (Casselman, unpublished data). The deep St. Lawrence trench in the vicinity of Yorkshire Bar is

TABLE 7. Categories of otolith characteristics used for recognizing lake trout of hatchery origin involving abnormal, protruding nodule and translucency. Frequency of occurrence of the various ranks for 250 marked hatchery lake trout from Lake Ontario 1988 is provided for both whole, intact otoliths and replicates made from transverse cross-sections. The replicates were made by embedding and thin-sectioning the otolith, mounting the sections, and etching their surface with dilute hydrochloric acid (2% for 1 min). The etched surface of the otolith was then replicated with thin cellulose acetate softened with acetone. The area of the abnormal protruding nucleus was measured and its size relative to the entire area of the section was calculated. Similarly, the size of the translucent or crystalline portion relative to the entire section was calculated. The relationship between rank, which subjectively classified the extent of the anomalous condition, and the relative size of the condition (ranging from 0--not observed, to 10--extremely conspicuous) was calculated, with rank as dependent variable: abnormal protruding nodule--RANK = 4.54 + 0.097% RELATIVE AREA, N = 53, r = 0.46, P<0.01; abnormal crystallization and translucency--RANK = 2.85 + 0.062% RELATIVE AREA, N = 53, r = 0.77, P<0.01. Values obtained from the predictive linear regression of the relative size of both abnormalities on rank are provided.

	Percent frequency of occurrence							
Classification	Abnormal protruding nodule		Abnormal translucency and crystallization		Combined abnormal nodule and translucency		Predicted average relative size of the abnormal protruding nodule	Predicted average relative size of the abnormal translucency and crystallization
rank	whole	sectioned	whole	sectioned	whole	sectioned	(%)	(%)
0	34.0	29.6	36.8	16.4	35.4	23.0	1.2	-5.2
1	4.8	5.2	4.8	19.2	4.8	12.2	3.4	4.6
2	6.0	6.0	11.2	15.2	8.6	10.6	5.6	14.4
3	9.2	6.6	13.8	12.4	11.5	9.5	7.9	24.2
4	7.2	9.4	15.3	13.6	11.3	11.5	10.1	33.9
5	5.3	5.0	12.6	16.4	9.0	10.7	12.3	43.7
6	10.3	9.0	4.2	6.4	7.3	7.7	14.6	53.4
7	10.2	14.4	1.3	0.4	5.8	7.4	16.8	63.1
8	12.0	13.2			6.0	6.6	19.0	72.8
9	1.0	1.0			0.5	0.5	21.3	82.6
10	0.6				0.3		23.5	92.3

sampled because juvenile studies in deep offshore waters adjacent to the bar would complement the early life-history studies conducted on the bar. The study also provides the opportunity to examine the species composition, predator-prey interaction, and environmental conditions in a typical Great Lakes deep-water lake trout nursery habitat.

Progress

Replicate bottom-set fine-mesh monofilament gill netting was conducted with nets ranging in mesh size from 0.5, 0.75, and 1 to 5 inches in 50-ft panels at depths of 30 m, 40 m, and 50 m in the St. Lawrence trench and at 60 m and 80 m outside Main Duck sill in the vicinity of the trench. Replicate bottom trawling was conducted at intervals of 30 m, 40 m, and 50 m in the trench. This sampling was similar to that conducted in 1988 and 1989. Oxygen and temperature data were collected, and a broad spectrum of water-chemistry measurements was made. An analysis of the catch and environmental data for this deep-water nursery habitat study is underway, but specific results will not be reported at this time. Generally, the catches are extremely consistent and are composed mainly of lake trout and smelt, but a few lake whitefish and alewife are caught. A total of 29 lake trout were taken in the trawls and 250 lake trout in the gill nets. As in previous years, it was apparent that the lake trout in deep water were significantly smaller than those caught shallower. Six of the lake trout caught in 1990 (2.2%) were unclipped, approximately the same relative number (2.5%) as in the 1989 lake trout sample obtained in this study.

As in other years, the fins, including the dorsal, of these unmarked lake trout were removed, dried, and examined in detail for deviations in normal size, shape, and fin-ray counts. Snouts were removed and examined for the presence of nose tags. Otoliths and scales were removed and examined microscopically for characteristics that have been shown to separate indigenous lake trout from those of hatchery origin (Casselman, submitted for publication). As a result of recent reviews, this methodology has been refined and improved.

Results from independent examinations of the fins, scales, and otoliths were combined and averaged to provide a percent chance that the lake trout were of hatchery

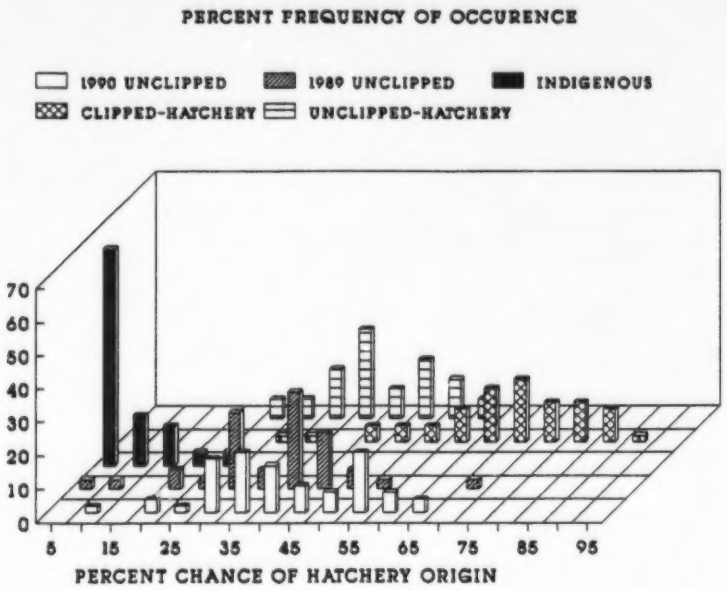

FIG. 1. Frequency of occurrence of the distribution of the percent chance of hatchery origin for samples of unmarked lake trout that were caught in OMNR Research and Assessment and NYDEC sampling programs during 1989 (N = 35) and 1990 (N = 49). These distributions are illustrated, along with the distributions for three sets of control samples: 1) 26 lake trout from an inland lake that were known to be indigenous; 2) 33 unmarked lake trout from an inland lake that were known to be of hatchery origin; and 3) 58 lake trout that were from Lake Ontario and were fin-clipped and of hatchery origin. Criteria used for determining percent chance of hatchery origin involved three sets of diagnostic characteristics: 1) relative size and shape of the fins and number of rays; 2) the degree of optical contrast and abnormal morphology of the otolith; and 3) the type and spacing of circuli and the relative location and conspicuousness of checks associated with the first annulus and the stocking check on the scales. If a fish is assigned as having a less than 20% chance of being of hatchery origin, it is considered to be indigenous since no unmarked or fin-clipped hatchery fish fell in this category. When using the 20% level of separation, it is possible that some fish in the 20 to 25% chance range might be indigenous and be inadvertently overlooked, since a few indigenous fish (4%) in the control lot were classified in this range.

origin. The maximum percentage that a fin was less than its normal length was estimated. A similar estimate was obtained for the maximum reduction in normal area, and anomalies associated with the number or shape of the rays were ranked from 0 to 10 (normal to grossly distorted, or fewer); this was subsequently converted to percent. The percents for these three characteristics were averaged to provide an overall estimate of fin anomalies. The scales were examined for a nucleus, indicative of hatchery growth, and an associated stocking check. This involved interpreting the spacing and size of the circuli and the relative location of the first annulus and the associated stocking check. The percent of the scales that had a regenerated nucleus corresponding in size to hatchery life was also recorded. These characteristics were then combined to classify the scales as either hatchery or native and to rank the strength of the classification from 0 to 10. The rank and classification were then converted to percent chance of hatchery origin; 0 equalled a 50% chance independent of the classification, whereas 10 in one extreme (indigenous) was a 0% chance and in the other extreme (hatchery) a 100% chance. Otolith characteristics involved the presence and extent of both an abnormal protruding nodule and translucency and crystallization. Both otoliths were examined independently and ranked from 0 to 10 for both anomalies. These ranks were converted to percent and averaged. Abnormal nodule, translucency, and crystallization are prevalent in the otoliths of lake trout of hatchery origin.

Otoliths provide important diagnostic characteristics for recognizing hatchery lake trout. However, quantitative criteria are required to make the interpretation and recognition objective. A systematic examination was conducted on otoliths of 250 lake trout that were captured and sampled in the juvenile habitat study in 1988. Otolith interpretations usually involve viewing the whole intact otolith at approximately 10 times magnification against a black background in 60% glycerol, lateral surface up. However, replicates made of the acid-etched surface of transverse otolith sections viewed at approximately 25 times magnification provide more distinct characteristics to evaluate the presence and extent of the protruding nodule and abnormal translucency and crystallization associated with lake trout of hatchery origin. The replicates of the sections made it possible to recognize the abnormal nodule in 4.4% more of the otoliths than did examination of the whole, intact otoliths (Table 7). Abnormal translucency and crystallization were recognized in 20.4% more replicated otoliths than in whole, intact otoliths. In this sample of hatchery lake trout, approximately 70% of the otoliths showed some degree of abnormal protruding nodule. Abnormal translucency and crystallation were detected in 84% of the sectioned, replicated otoliths. A subsample was examined to determine the precise relationship between rank assigned to the anomaly and the size of the abnormal portion relative to the total cross-sectional area. For both otolith anomalies, the relationships were

highly significant (Table 7--caption). Predictive regressions indicated that a classification rank of 1 corresponded to an abnormally protruding nodule that was approximately 3% of the total cross-sectional area. At the other extreme, a classification rank of 10 indicated a protruberance that was approximately 24% of the total area. Abnormal translucency and crystallization ranked at 1 corresponded to approximately 5% abnormal area, whereas a classification rank of 10 indicated that approximately 92% of the cross-sectional area was abnormal. This study provided specific quantitative criteria that defined the various ranks.

The overall percent chance of hatchery origin for a particular fish was obtained by combining fin, scale, and otolith characteristics equally. The frequency distribution and boundaries for the fin, scale, and otolith characteristics, as they pertained to percent chance of hatchery origin, were established in a study conducted in 1989. It involved and defined the percent chance of hatchery origin of a sample of clipped hatchery lake trout from Lake Ontario, unclipped lake trout from an inland lake that were known to be of hatchery origin, and another set of lake trout from an inland lake that were known to be indigenous (Fig. 1). These various samples provided guidelines for assigning unknowns. In the 20% to 25% chance range, there was some overlap between unclipped hatchery fish and indigenous fish. However, no unclipped hatchery fish had a 20% or less chance of being of hatchery origin. This indicates that 20% would provide a conservative boundary for assigning origin. However, when this limit is used, some indigenous lake trout (4%) might be missed because they would inadvertently be classified as being of hatchery origin. Hence, this method would provide a conservative estimate of the occurrence of indigenous lake trout. It is unfortunate that indigenous lake trout must be recognized and separated from hatchery fish by default, involving hatchery-fish characteristics. Nevertheless, the method has proved to be reliable and consistent.

In addition to the 6 unclipped lake trout taken in this juvenile lake trout study, 37 unmarked lake trout were taken in other OMNR sampling programs at Glenora in 1990. Of these, 34 came from the Research project that studies the fish-community dynamics of the deep waters of the Outlet Basin of Lake Ontario (Casselman et al. 1991). In addition, samples from 6 unclipped fish were supplied by Cliff Schneider, NYDEC. The fins, scales, and otoliths of all these unmarked fish (49) were analyzed independently and classified by each of the various criteria indicative of hatchery origin. Three of these unmarked fish were considered to be indigenous, with less than a 20% chance of being of hatchery origin (Fig. 1). One small lake trout was a yearling caught on July 27, 125 mm TL, 114 mm FL, 11.6 g in weight, condition factor (K) = 0.70 (TL), from the 1988 year class (spawning), and classified as indigenous with only a 10% chance of being of hatchery origin. Another lake trout was caught on September 18 by NYDEC in the vicinity of Charity Shoal; it was a larger fish, 553 mm long, 1720 g in weight, from the 1984 year class (spawning), and was classified as indigenous with an 18% chance of being of hatchery origin. The third unmarked lake trout was caught on May 22 at station 3 in the Outlet Basin in the vicinity of Timber Island, 270 mm FL, 216 g in weight, from the 1987 year class (spawning), and was classified as indigenous with an 18% chance of being of hatchery origin.

In 1989, 11% (4) of the 35 unmarked lake trout that were examined were considered to be indigenous (Fig. 1) as compared with 6% (3) of the 49 unmarked fish examined in 1990. For this group of 7 indigenous lake trout caught in 1989 and 1990, one was from the 1981 year class (spawning) and another was from the 1988 year class. However, two fish, one taken in 1989 and another in 1990, were from the 1984 year class. It is not surprising that the first multi-occurrence of a year class of indigenous lake trout was associated with the 1984 year class, because in 1984, there was the first large, significant increase (four times the previous year) in the size of the spawning population that congregated on traditional spawning grounds such as Yorkshire Bar. Also, three lake trout were from the 1987 year class--two taken as yearlings in 1989 and one in its third calendar year of life in 1990.

It is now apparent that small numbers of indigenous lake trout are present in Lake Ontario and that some have reached the young subadult stage (age 5). Four (57%) of the 7 indigenous lake trout caught in the past two years came from two year classes. Time will tell whether the 1984 and 1987 lake trout spawnings produced significantly more recruits.

Future Directions

Although the numbers are small, it is now apparent that initial natural recruitment of lake trout has progressed to the yearling and possibly to the subadult stage. All unclipped lake trout should be examined carefully. The snouts should be removed, and fins, scales, and otoliths should be collected and examined for anomalous conditions that are indicative of hatchery origin. Continued sampling of the juvenile habitat should be conducted to describe environmental conditions and species interactions, to determine whether the numbers of indigenous lake trout are increasing, and to measure the contribution of various year classes. Substantial recruitment to the juvenile stage will first be documented by sampling the juvenile habitat. This habitat in midsummer ranges from approximately 27 to 60 m. To date, this juvenile-habitat study has focused only on the deep St. Lawrence trench in the middle of the east end of Lake Ontario. It is now apparent that there are large numbers of mature females frequenting the inshore shallows of the east end of Lake Ontario. Additional surveys of deep-water areas adjacent to these inshore shallows should be conducted. One such site is a deep trench inside the upper gap at the confluence of the Bay of Quinte and the Outlet Basin of Lake Ontario.

Alternative methods for selectively sampling juvenile lake trout should be developed. Although it is thought that they are strongly bottom-oriented, they may migrate up into the water column at low light intensities to forage on large zooplankton. Also, active sampling techniques should be developed to attempt to sample emergent fry on the spawning grounds prior to and during their migration to the deep-water nursery habitat.

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